

PB-234 185

IMPACT OF MOTOR GASOLINE LEAD ADDITIVE REGULATIONS ON  
PETROLEUM REFINERIES AND ENERGY RESOURCES, 1974-1980  
PHASE I

ARTHUR D. LITTLE, INCORPORATED

PREPARED FOR  
ENVIRONMENTAL PROTECTION AGENCY

MAY 1974

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| 1. REPORT NO.<br>EPA-450/3-74-032-A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2.                                                                                                     | 3. RE PB 234 185                                      |
| 4. TITLE AND SUBTITLE<br>IMPACT OF MOTOR GASOLINE LEAD ADDITIVE REGULATIONS<br>ON PETROLEUM REFINERIES AND ENERGY RESOURCES -<br>1974 - 1980 PHASE I                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                        | 5. REPORT DATE<br>May 1974                            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                        | 6. PERFORMING ORGANIZATION CODE                       |
| 7. AUTHOR(S)<br>N. A.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                        | 8. PERFORMING ORGANIZATION REPORT NO.                 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Arthur D. Little, Incorporated<br>Acron Park<br>Cambridge, Massachusetts 02140                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                        | 10. PROGRAM ELEMENT NO.                               |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                        | 11. CONTRACT/GRANT NO.<br>68-02-1332<br>Task No. 4    |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>Environmental Protection Agency<br>Office of Air and Water Programs<br>Office of Air Quality Planning and Standards<br>Research Triangle Park, NC 27711                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                        | 13. TYPE OF REPORT AND PERIOD COVERED<br>Final Report |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                        | 14. SPONSORING AGENCY CODE                            |
| 15. SUPPLEMENTARY NOTES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                        |                                                       |
| 16. ABSTRACT<br>The report presents results of a study to assess the impact on operations of petroleum refineries and on energy resources of two regulations promulgated by the Environmental Protection Agency to control the level of lead additive in motor gasoline. The first of these regulations requires the availability of low-octane, lead-free gasoline for vehicles which will be equipped with lead sensitive catalytic converters designed to meet 1975 automotive emission standards. For health reasons, the second regulation requires a gradual phase-down of the lead content of the total gasoline pool (including higher octane gasoline to satisfy the remaining high-compression ratio engines). The study considers separately the impact of each regulation. Effects on overall refinery yields, refinery operation flexibility to maximize production of gasoline and/or heating oils, and on energy resources requirements have been considered. Other parametric studies evaluate suppositions of a need for a higher octane lead free gasoline and a higher demand for lead free gasoline than now forecast. |                                                                                                        |                                                       |
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| 17. KEY WORDS AND DOCUMENT ANALYSIS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                        |                                                       |
| a. DESCRIPTORS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | b. IDENTIFIERS/OPEN ENDED TERMS                                                                        | c. COSATI Field/Group                                 |
| Gasoline<br>Gasoline Engine<br>Tetraethyl Lead<br>Octane Number<br>Refineries                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Lead-free gasoline<br>Lead phase-down<br>Motor Gasoline additives                                      | 13B                                                   |
| 18. DISTRIBUTION STATEMENT<br><br>Unlimited                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 19. SECURITY CLASS (This Report)<br>Unclassified<br><br>20. SECURITY CLASS (This page)<br>Unclassified | 21. NO. OF PAGES<br>132<br><br>22. PRICE              |

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REFINERIES AND ENERGY  
RESOURCES - 1974-1980  
PHASE I**

by

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Contract No. 68-02-1332 Task No. 4

EPA Task Officer: David R. Patrick

Prepared for

ENVIRONMENTAL PROTECTION AGENCY  
Office of Air and Water Programs  
Office of Air Quality Planning and Standards  
Research Triangle Park, N. C. 27711

May 1974

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Publication No. EPA-450/3-74-032-a



## ABSTRACT

The report presents results of a study to assess the impact on operations of petroleum refineries and on energy resources of two regulations promulgated by the Environmental Protection Agency to control the level of lead additive in motor gasoline. The first of these regulations requires the availability of low-octane, lead-free gasoline for vehicles which will be equipped with lead sensitive catalytic converters designed to meet 1975 automotive emission standards. For health reasons, the second regulation requires a gradual phase-down of the lead content of the total gasoline pool (including higher octane gasoline to satisfy the remaining high-compression ratio engines). The study considers separately the impact of each regulation. Effects on overall refinery yields, refinery operation flexibility to maximize production of gasoline and/or heating oils, and on energy resources requirements have been considered. Other parametric studies evaluate suppositions of a need for a higher octane lead free gasoline and a higher demand for lead free gasoline than now forecast.

#### ACKNOWLEDGMENTS

In preparing this report, several people in addition to the principal author, Arthru D. Little, Incorporated, made significant contributions. We wish to acknowledge the guidance and direction provided by the Petroleum Refinery Task Force including Messrs. David R. Patrick, Richard K. Burr, and Gilbert H. Wood.

Throughout the project, considerable technical assistance was obtained from Dr. James R. Kittrell, Associate Professor, and Dr. William L. Short, Professor, both of the Chemical Engineering Department, University of Massachusetts. Their assistance in both defining the areas of concern and analyzing the results is especially appreciated.

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## I. SUMMARY AND CONCLUSIONS

In February 1974, the EPA asked Arthur D. Little, Inc. (ADL) to review the effects of the EPA regulations which require the availability of lead-free gasoline and the gradual phase-down of the lead content of the total gasoline pool. The EPA required that preliminary results be reported to the EPA in early April, and the final written report be completed by the end of April, 1974. Although previous studies have been conducted and published for the EPA concerning the problems associated with supplying lead-free gasoline and reducing lead content of gasoline, the EPA felt that this review was needed for the following reasons:

- Since the previous studies had been conducted, more recent assessments of the status of mobile source emission standards and lead-free gasoline requirements have become available.
- Rapid large increases in crude oil costs and associated product prices have occurred recently due in part to increased national energy demand and limited supply. Since refinery processing options are inherently sensitive to costs of raw materials and products, and since these options can not be fully analyzed manually without severe oversimplification, the EPA felt that a computer analysis of the impact of the lead regulations incorporating current prices was needed.
- Natural gas production has continued to decline since the previous studies. This decline has caused increased substitution of volatiles for this marginal supply with associated increase in LPG prices.
- Assessments of results of recent EPA test programs and statements by the automobile manufacturers indicate that the fuel economy increase for catalyst-equipped vehicles will be greater than previously projected. Not only will the fuel economy benefits compensate for the previous 3.5% penalty due to lowered compression ratios to reduce NO<sub>x</sub> emissions and prepare for low-octane, lead-free gasoline but the benefits also will offset the entire 10% penalty for the total of all of the air pollution controls. This change in fuel economy greatly affects projections of gasoline demand and, thus, refinery operations.
- Since the last studies, refinery process unit capacities have increased and refining technology, particularly in the development of superior catalysts for catalytic cracking and reforming, has continued to improve.
- Potential crude supply restrictions to domestic refineries, as illustrated by the recent Arab oil embargo indicate the necessity of maintaining the refinery flexibility to vary output product mix to meet seasonal demands, e.g., gasoline and fuel oils.

The intent of this study was to evaluate the effect of lead phase-down and lead-free gasoline scenarios on (1) crude oil requirements to meet projected petroleum product demands (e.g., gasoline, jet fuel, petrochemical feedstocks, (2) associated net energy consumption for refining, (3) capital investment (or strain on construction industry) and gasoline costs, and (4) flexibility of the refining industry to adjust the product mix, particularly to seasonal variations of gasoline and fuel oil demands. To achieve this, three scenarios were evaluated for each year considered:

- Scenario A -- No Lead Regulations (minimal presence of lead-free gasoline, 3cc/gal lead maximum in regular and premium grades, and distribution of regular and premium in the gasoline pool assuming no additional automotive emission controls).
- Scenario B -- Significant Lead-Free Gasoline Marketing, but with No Lead Phase-Down (increase in lead-free pool, with increased lead-free percentage being proportionally subtracted from premium and regular grades; 3cc/gal lead maximum in regular and premium grades).
- Scenario C -- Lead-Free Gasoline with Promulgated Phase-Down (same gasoline distribution as Scenario B but with lead phase-down as promulgated in the December 6, 1973 Federal Register).

The scope of this study was to consider the impact of the lead regulations upon the manufacture of petroleum products. Additional impacts involved in distributing and marketing lead-free gasolines have been analyzed in previous studies.

The Federal Energy Office (FEO) issued forecasts in mid-December of United States 1974 petroleum product demands in an unconstrained environment. Several possible supply scenarios were postulated and resultant product shortages defined. We have used these estimates of 1974 petroleum product demands as the basic source of our model inputs with only minor adjustments made to reflect more recent data in certain instances.

The results of this overview study indicate that:

- Most large, modern, efficient refineries (which represent the major source of supply to the U.S. marketplace), will suffer little penalty from manufacturing lead-free gasoline and the lead phase-down. A key premise is that moderate-octane gasoline (refinery target of 92/84 RON/MON gasoline to allow more than ample margin to ensure minimum octane levels of 91/83 RON/MON) will provide satisfactory performance in post-1974 automobiles. (It is recognized that an overview study of

this scope does not address itself to analysis of the specific potential problems of some small or atypical refiners. However, it should be noted that the promulgated lead phase-down schedule does not require compliance by small refiners for the first two years).

- o Through 1976 there is essentially no crude oil penalty for either B vs. A or C vs. B.
- o The average crude oil penalty for 1977 through 1980 is 30,000 - 44,000 barrels per calendar day (B/CD) (.2-.3% of A) for B vs. A and approximately 28,000 B/CD for C vs. B (.1% of A).
- o Through 1976 there is essentially no net energy input penalty for either B vs. A or C vs. B.
- o The average net energy input penalty (fuel oil equivalent barrels) for 1977-1980 is about 10,000-20,000 B/CD (.1% of A) for B vs. A and 20,000-30,000 B/CD (.1-.2% of A) for C vs. B.
- o Through 1976 there is essentially no capital investment penalty for either B vs. A or C vs. B.
- o The average yearly capital investment penalty for 1977 through 1980 is 150 million dollars (1974 dollars) for B vs. A and 220 million dollars for C vs. B. These incremental capital investment figures are extremely sensitive to the process routes selected. Phase II of this study will examine capital investment in more detail, in order to provide further information on this point.
- o The incremental process unit construction due to the lead regulations is insignificant compared to the construction necessary to meet the growth of overall petroleum product demand.
- o Through 1976 there is essentially no net economic penalty (cents per gallon of gasoline) for either Scenario B vs. A or C vs. B.
- o For 1977 through 1980, the average net economic penalty is less than .1 cents/gallon of lead-free gasoline for B vs. A and less than .1 cents/gallon of total gasoline for C vs. B.
- o There is essentially no net energy input penalty and no loss of flexibility of product yields for either Scenario B vs. A or C vs. B for current refinery capacity limitations.

TABLE I-1  
REFINERY IMPACT OF EPA LEAD REGULATIONS

| Average Yearly Penalty                         |                  |                  |
|------------------------------------------------|------------------|------------------|
|                                                | <u>1974-1976</u> | <u>1977-1980</u> |
| <b>Δ Crude [MB/D]</b>                          |                  |                  |
| Lead-free                                      | 0                | 30-44            |
| Lead Phase-down                                | <u>0</u>         | <u>28</u>        |
| Total                                          | 0                | 58-72            |
| <b>Δ Net Energy Input [FOE MB/D]</b>           |                  |                  |
| Lead-free                                      | 2                | 10-20            |
| Lead Phase-down                                | <u>2</u>         | <u>20-30</u>     |
| Total                                          | 4                | 30-50            |
| <b>Δ Capital Investment [\$10<sup>9</sup>]</b> |                  |                  |
| Lead-free                                      | 0                | .15              |
| Lead Phase-down                                | <u>0</u>         | <u>.22</u>       |
| Total                                          | 0                | .37              |
| <b>Δ Gasoline Cost [¢/gal]</b>                 |                  |                  |
| Lead-free <sup>1</sup>                         | (.02)            | .02              |
| Lead Phase-down <sup>2</sup>                   | 0                | .03              |
| Combined <sup>2</sup>                          | (.01)            | .04              |

1. Apportionated over lead-free gasoline production only.
2. Apportionated over total gasoline production.



## II INTRODUCTION

The intent of the study was to evaluate the effect of various lead phase-down and lead-free gasoline scenarios on (1) increased crude oil requirements to meet projected unrestrained petroleum product demands (e.g., gasoline, jet fuel, petrochemical feedstocks, etc.) (2) associated net energy consumption in refining, (3) capital investment (or strain on construction industry) and increased gasoline costs, and (4) flexibility of the refining industry to adjust the product mix, particularly seasonal variations of gasoline and fuel oil demands. To achieve this, three scenarios were evaluated for each year considered:

- Scenario A -- No Lead Regulations (minimal presence of lead-free gasoline, 3cc/gal lead maximum in regular and premium grades, and distribution of regular and premium in the gasoline pool assuming no additional automotive emission controls). The specific grade distribution is shown in Table II-1.
- Scenario B -- Significant Lead-Free Gasoline Marketing (availability required by EPA regulation promulgated in the January 10, 1973 Federal Register), but with No Lead Phase-Down (increase in lead-free pool, with increased lead-free percentage being proportionally subtracted from premium and regular grades; 3cc/gal lead maximum in regular and premium grades). The specific grade distribution is shown in Table II-1.
- Scenario C -- Lead-Free Gasoline with Promulgated Phase-Down (same gasoline grade distribution as Scenario B but with lead phase-down as promulgated in the December 6, 1973 Federal Register).



TABLE II-1  
Gasoline Grade Requirements by Percent

A. No Lead Regulations

|                             | <u>1974</u> | <u>1975</u> | <u>1976</u> | <u>1977</u> | <u>1978</u> | <u>1979</u> | <u>1980</u> |
|-----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| <u>Grade Distribution %</u> |             |             |             |             |             |             |             |
| Premium<br>(100 RON)        | 40          | 38          | 39          | 40          | 41          | 42          | 43          |
| Regular<br>(94 RON)         | 58          | 60          | 59          | 58          | 57          | 56          | 55          |
| Lead-Free<br>(92 RON)       | 2           | 2           | 2           | 2           | 2           | 2           | 2           |

B. Lead-free with No Lead Phase-down

Percent of Pool

|           |    |    |    |    |    |    |    |
|-----------|----|----|----|----|----|----|----|
| Premium   | 37 | 34 | 28 | 22 | 19 | 15 | 11 |
| Regular   | 56 | 51 | 42 | 34 | 28 | 22 | 17 |
| Lead-free | 7  | 15 | 30 | 44 | 53 | 63 | 72 |

C. Lead-free With Lead Phase-down<sup>a</sup>

|                                                                  |     |     |     |     |     |     |
|------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|
| Promulgated lead<br>phase-down, pool<br>average. grams/gal. ---- | 1.7 | 1.4 | 1.0 | 0.8 | 0.5 | 0.5 |
|------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|

|                                                                                            |      |      |      |      |      |      |
|--------------------------------------------------------------------------------------------|------|------|------|------|------|------|
| Allowable grams of<br>lead per gallon<br>of leaded gasoline <sup>2.0-2.2<sup>b</sup></sup> | 1.99 | 1.97 | 1.74 | 1.65 | 1.27 | 1.66 |
|--------------------------------------------------------------------------------------------|------|------|------|------|------|------|

a. Same distribution pattern used as in Lead-free (Case B)

b. Current national average

The impact of phase down of lead in gasoline was evaluated during the interval 1974-1980 by consideration of the following cases, for each Scenario.

- Case 1 -- Simulation of U.S. Refining industry by a single composite crude slate, using best estimates of product growth and annual average distribution for each year, 1974-1980 inclusive.
- Case 2 -- A parametric study, varying only the clear octane of the lead-free grade from 92/84, RON/MON, (Case 1) to 93/85 RON/MON (Case 2 ). Case 2 therefore evaluates variations in the projected difference between the current pool octane and the pool octane required with lead phase-down.
- Case 3 -- A parametric study, varying only the rate of growth of gasoline demand from 4%/year (Case 1) to 7%/year (Case 3 ). Case 3 thus evaluates uncertainties in the gasoline growth projection.
- Case 4 -- A parametric study, varying only the rate of introduction of lead-free gasoline from Scenarios B & C in Case 1. Here, the amount of lead-free gasoline in the total pool was reduced for Scenarios B and C with the amount reduced distributed proportionally between the premium and regular grades. This case evaluates uncertainties in projections of market penetration of lead-free gasoline. The gasoline distributions used are shown below:

|           | <u>GRADE DISTRIBUTION %</u> |      |        |      |
|-----------|-----------------------------|------|--------|------|
|           | Case 1                      |      | Case 4 |      |
|           | 1976                        | 1979 | 1976   | 1979 |
| Premium   | 28                          | 15   | 35     | 23   |
| Regular   | 42                          | 22   | 45     | 31   |
| Lead-Free | 30                          | 63   | 20     | 46   |

- Case 5 -- Restricted Capacity Evaluations - a parametric study, similar to Case 1 except the capacity of each refining unit was restricted to the percent of average U.S. crude capacity as reported in the April 2, 1973 Oil and Gas Journal. Hence, whereas Case 1 can be considered to be new grass roots refineries from 1974 through 1976, Case 5 represents existing average U.S. capacity limitations. As a consequence, Case 5 was evaluated only for 1974, 1975, and 1976, the time period before significant new capacity could be installed.

- Case 6 -- Refinery Flexibility Studies - The unit capacities were again fixed as in Case 5, and the ability of the industry to swing from maximum gasoline (9.5 RVP on gasoline based on 1973 Summer data of B.O.M.) to maximum distillate (12 RVP on gasolines based on 1972 winter data of B.O.M.) was evaluated. LPG production was restricted to 2.6-2.8% yield on crude in the summer (1973 B.O.M. data) and 2.8% minimum in the winter. The ratio of distillate to residual fuel was fixed at 2.58 for 1974 in accordance with historical B.O.M. data and successively reduced to 2.19 in 1976 reflecting a more rapid growth in domestic residual fuel production.
- Case 7 -- A parametric study, varying (reducing) only the percentage of premium gasoline in the total pool (1979) and increasing regular accordingly to examine uncertainties in projecting future gasoline grade distribution. The pool distribution used was:

|           | <u>Scenario A</u> | <u>Scenarios B and C</u> |
|-----------|-------------------|--------------------------|
| Premium   | 30%               | 12%                      |
| Regular   | 68%               | 25%                      |
| Lead Free | 2%                | 63%                      |

### III MODEL RESULTS

#### A. Base Cases

##### Case 1 - Actual Refinery

The purpose of Case 1 was to examine the effect of producing lead-free and reduced lead content motor gasolines each year from 1974 to 1980 in an unrestricted refining environment. For this series of runs we specified product demands, specifications, and cost of raw materials. The refining processing sequence was then allowed to optimize. We call this series of runs our "actual" refinery in that we have composited many of our parallel, blocked out processing options allowed in our more "complex" refinery, which is discussed next in this section. We selected optimum feed blends to some of the downstream processing operations such as hydrocracking, coking and alkylation to more closely simulate the actual flexibility available in a typical refinery.

With the greatly increased costs of crude oil and the limited supply and price competition for volatiles and natural gas, the refining processing sequence selected considerably more hydrocracking than is practiced today. This process has a large volume gain even while producing substantial volumes of middle distillates as co-products. While the competitive catalytic cracking process also exhibits a volume gain, it is not the same magnitude as for hydrocracking. Also, catalytic cracking inherently requires that some of the hydrocarbon feedstock be converted and consumed as catalyst coke. As shown in Section III C, changing process sequences appears to have minimal impact on either crude penalty or energy penalty.

The optimum clear gasoline pool octane level for 1974 was calculated to be 89.4/81.2 (RON/MON) which is not much different from the anticipated average today, although many variations exist in this projection.

In most years the capital expenditures required for the reduction of lead content were actually lower than for the base scenarios. The primary reason for this is that, for this case, it is most attractive to increase clear octane levels via the catalytic cracking/alkylation processing route (including increased conversion on the catalytic cracker to produce higher octane gasolines) while reducing hydrocracking/catalytic reforming. Although this results in a less efficient raw material usage (because of the loss in hydrocracking yield gain) it does require less overall capital.

As seen in the summary tables, the crude oil, energy, operating cost, and capital cost penalties for the lead regulations are relatively insignificant, and in some situations there appears to be no penalty at all. The maximum crude penalty due to lead phase-down (C-B) is 62,000 B/CD; the maximum economic penalty is 4¢/Bbl; and the maximum net energy input penalty is 75,000 B/D. It should be noted that these values are maximums and thus tend to overstate some of the penalties. For example, although the maximum net energy input penalty is 75,000 B/D, the average penalty for 1974 through 1976 is only 4,000 B/D and for 1977 through 1980 is only 45,000 B/D. Also, as discussed in III C, even these averages are probably overstated because of various model constraints.

#### Case 1 - Complex Refinery

The basic assumptions and methodology underlying this case were essentially the same as Case 1 - Actual Refinery. Again, product demands and specifications were fixed along with raw material availability and cost. The refinery was allowed to optimize for each case. However, this refinery model had a large number of parallel operating and blending operations (relative to Case 1 Actual) for downstream processes. One other important difference between the "complex" and "actual" cases was that for the actual case we allowed the hydrocrackers to make substantial volumes of middle distillates as co-products which was not allowed at all in the complex cases. Hence, the optimum hydrocracking capacity chosen for the complex cases was less than for the actual.

The crude oil, energy and economic penalties are relatively insignificant for each of the lead regulations. The maximum crude oil penalty (C-B) is 105,000 B/D, the maximum net energy input penalty for C vs. B is 17,000 B/D, the largest capital investment penalty is \$460,000,000 (C-B in 1978) and the maximum economic penalty is 3.9¢/barrel. As for Case 1 Actual, it should be noted that these values are maximums and thus tend to overstate some of the penalties. For example, although the maximum crude oil penalty is 105,000 B/D for C vs. B, there is no penalty for 1974 through 1976 and an average of less than 22,000 B/D for 1977 through 1980.



## B. Parametric Studies

### Case 2 - Actual Refinery

The purpose of this case was to examine the effects of producing a lead-free grade of 93/85 RON/MON instead of the 92/84 produced in Case 1 (and all other subsequent cases). As expected the higher octane product required a greater energy consumption and increased operating costs resulting in a greater economic penalty than Case 1. The maximum crude penalty (C-B) is 86,000 B/D; the maximum net energy input penalty (C-B) is 95,000 B/D and the maximum economic penalty is 5.2¢/bbl. As for Case 1, it should be noted that these values are maximums and thus tend to overstate some of the impacts. For example, although the maximum crude oil penalty is 86,000 B/D for C-B, the average penalty is only 6,000 B/D for 1974 through 1976 and is less than 42,000 B/D for 1977 through 1980. Also it is significant to note that once again the most attractive way to increase clear octane numbers for the pool is via catalytic cracking/alkylation replacing hydrocracking/catalytic reforming.

For Case 1 the economic effect was most pronounced in comparing scenario C versus B. In Case 2 the major delta increase in catalytic cracking/alkylation occurs in comparing scenario B versus A, and as a result there is a capital investment penalty in 1980 associated with lead phase-down (C versus B).

One must caution that these results are only valid comparing 92/84 product to 93/85 and should not be extrapolated to higher octanes. Above the octane levels studied, one would expect other capital intensive processing such as light straight-run gasoline isomerization to be selected which would cause a more rapid increase in overall capital requirements.

It should be noted that the primary purpose of this case is to determine the sensitivity of the model to specific octane levels. The evaluation of this case is not meant to suggest that 93/85 RON/MON will be necessary for post-1974 vehicles. Rather, all post-1974 model year vehicles will be satisfied by 91/83 RON/MON through the vehicle life (i.e., including effect of increased octane requirement with mileage). This conclusion is based on recent communications with the automobile manufacturers in addition to their numerous public statements.

### Case 3 - Actual Refinery

In Case 3 we assumed that the overall refinery gasoline production would increase 7% a year rather than the 4% average annual growth which was used in all other cases.



Since the other cases assuming a 4% gasoline growth (with distillates and residual fuel increasing faster) result in an average decline in gasoline yield of about 4% over the time period studied, this case countered that trend and maintained essentially constant gasoline yield. In the later years (such as 1979 and 1980) there are increased energy and economic penalties with the lead phase-down. As stated previously, it is attractive for certain instances to increase gasoline (or distillate) yields via hydrocracking because of the related large associated volume gain. However, as the need for high clear octane numbers are required, the introduction of high severity catalytic cracking and alkylation becomes more attractive. The "A" Scenarios desire a high percentage of hydrocracking to provide the higher gasoline growth rates and these percentages are in general about the same order of magnitude as Case 1. However, in Case 3 Scenarios B and C, it is necessary to maintain this high level of hydrocracking versus Case 1 to manufacture the required volume of gasoline complemented by increased reforming severity to meet octane requirements. Thus there is the need to process more raw materials to replace the gasoline yield loss due to increasing reformer severity.

The major "penalty" associated with Case 3 is thus the total crude run, which in 1980 has risen to 21,382,000 B/D (Scenario C) versus 19,642,000 B/D for Case 1. In general, the maximum economic, crude oil, and energy penalties (C-B) are greater for Case 3 than any other case: 11.1/Bbl., 127,000 B/D crude oil and 155,000 B/D net energy input. As for the other cases, these maximum values tend to overstate the impact. For example, although the maximum crude oil penalty is 127,000 B/D for C-B, the average is 6000 B/D for 1974 through 1976 and 28,000 B/D for 1977 through 1980. Furthermore it should be restated that we do not consider Case 3 to be likely. However, Phase II should include a parametric case with a slightly greater gasoline growth rate than the base (4%) but still less than the 7% of Case 3.

#### Case 4 - Actual Refinery

Case 4 runs were to study if a lower market penetration of lead-free gasoline (B versus A) would result in increased penalties for lead phase-down (C versus B). Only two years were studied (1976 and 1979) and the penalties for B versus A were reduced and C versus B increased. However, the deviations from Case 1 were not considered of sufficient magnitude to alter the overall conclusions of this analysis. The differences are summarized below for 1979.

|                                 | <u>Case 1 (Actual)</u> |            | <u>Case 4 (Actual)</u> |            |
|---------------------------------|------------------------|------------|------------------------|------------|
|                                 | <u>B-A</u>             | <u>C-B</u> | <u>B-A</u>             | <u>C-B</u> |
| <u>1979 Penalty</u>             |                        |            |                        |            |
| Δ Crude MB/CD                   | 42                     | 35         | 10                     | 151        |
| Δ Net Energy Input,<br>MB/CD    | 34                     | 75         | 10                     | 111        |
| Δ Total Gasoline<br>Cost ¢/Bbl. | 1.4                    | 4.0        | (0.5)                  | 8.1        |

It should again be noted that these are maximum values. We looked only at 1976 and 1979 and thus can not present average values for the time period. However, it is reasonable to think that the average may be considerably less than the maximum, in the same manner as the other cases. Furthermore it should be noted that recent EPA communications with the automobile industry still confirm earlier conclusions that lead tolerant vehicles that can meet the 1975 emission standards while maintaining fuel economy equivalent to catalyst-equipped vehicles will not be available in the near future. Thus, although Case 4 has value as a sensitivity analysis, the probability of Case 4 occurring is very low.

#### Case 5 - Restricted Capacity Refinery

The purpose of Case 5 runs was to study the impact of the lead regulations during the time period when refinery operations would be essentially restricted to present processing capability. For this series of runs we established the percent of crude capacity for the major downstream processing units based on the 1973 refining data in the April 2, 1973 Oil and Gas Journal. These ratios were held constant throughout the 1974 to 1976 period, which was considered the time period during which no major deviation from current processing flexibility could be achieved.

The major difference in the processing sequences chosen in this case was the large reduction in hydrocracking capacity with attendant increases in catalytic cracker feed rate, conversion, and alkylation production. It is significant to note that by choosing high conversion catalytic cracking (which produces higher octane gasoline) the optimum refinery clear octane pool increased from 89.4 to 90.5 (case 1). The optimum catalytic reforming severity increased from 91 to 92 clear research octane number at the same time. Thus there was a substantial decrease in the optimum gasoline lead content in these runs.

We feel there is a definite trend towards a reduction in optimum lead content in refinery gasoline pools due to the following reasons: (1) higher catalytic cracked gasoline octane numbers resulting from higher conversions, zeolite catalyst operation and hydrogenation of catalytic cracker feed, (2) improvements in reformer technology due to better catalyst stability which allows lower operating pressures and better yield/octane relationships, (3) a change in reforming economics due to increased value of by-products such as hydrogen, fuel gas and C3/C4 concurrent with the curtailed supply of natural gas.

There are essentially no penalties for either of the lead regulations for Case 5.

#### Case 6 - Restricted Capacity Refinery

The purpose of Case 6 was to examine the impact of lead regulations on the ability of refineries to maintain a flexibility in changing product mixes due to seasonal swings in demands and specifications. This was the only case in which we allowed variations in prime product demands and seasonal specifications. Although we allowed overall gasoline volume to vary, we maintained the same ratios between premium, regular, and lead-free gasoline as for the other cases between scenarios A, B, and C. We also maintained a constant distillate to low sulfur residual fuel oil ratio for all scenarios. For summer operation we reduced the maximum gasoline RVP specification to 9.5 and increased the composite gasoline product price 3¢/gal. above the equilibrium values calculated in Case 5. Distillate and fuel oil product netbacks were used equivalent to those calculated in Case 5. We had originally planned to reduce LPG production for summer operation due to the historical seasonal decrease in demand for this product. However, in the summer months of 1973 the average refinery production of LPG actually increased to the upper range of the historical average annual demands (due to natural gas supply curtailment). We would expect this situation to continue so the summer LPG product demand was left at the 2.6-2.8 percent yield used for the annual average demand in other cases.

Despite the reduced vapor pressure specification it was possible to increase gasoline production above Case 5 results by increasing catalytic cracker intake (and sometimes conversion). However the small gains realized indicated that our case 5 refinery runs were essentially at maximum gasoline production.

For the winter operation we increased the allowable maximum RVP to 12 and required a minimum LPG production at the upper range of summer operation (2.8%). We increased distillate and fuel oil refinery netbacks 3¢/gal. above the equilibrium values calculated in Case 5 and reduced gasoline prices accordingly.

In order to achieve the required LPG production (and at the same time maintain maximum production of distillates/residual fuel oil) it was necessary to significantly increase the reforming severity to approximately 97 to 98 clear RON. Then gasoline lead additions declined to an average of 1.0 grams per gallon or less. We feel that the refinery LPG supply, demand, price relationships should be investigated in more detail before firm conclusions are drawn from this analysis but we believe it is directionally correct. It is interesting to note that the refinery achieved about a 12-13 percentage crude swing between maximum gasoline and fuel products production. In no cases did the proposed lead-free and reduced lead regulations appear to inhibit flexibility.

The energy penalty for this case is zero and the crude penalty is also zero. Economic penalties were not calculated.

#### Case 7 - Actual Refinery

This case was only run for one year (1979) to test the sensitivity of a lower percent premium versus regular in the leaded gasoline grades. In general, this case increased the cost of producing lead-free gasoline (because the optimum clear octane pool in Case A is lower) without significantly changing the energy impact. However, the economic summary shows that the cost penalty for the phase-down is smaller for Case 7 than for Case 1. The comparison is summarized below.

|                                  | Case 1     |            | Case 7     |            |
|----------------------------------|------------|------------|------------|------------|
|                                  | <u>B-A</u> | <u>C-B</u> | <u>B-A</u> | <u>C-B</u> |
| <u>1979 Penalty</u>              |            |            |            |            |
| Δ Crude (MB/CD)                  | 42         | 35         | 26         | 75         |
| Δ Total Gasoline<br>Cost (¢/Bbl) | 2.2        | 4.0        | 6.7        | 2.9        |
| Δ Net Energy Input<br>(MB/CD)    | 34         | 75         | 26         | 45         |

### Description of Summary Tables

Table III-1 contains a summary of the crude intake requirements for all cases. The total refinery crude intake for Scenario A is shown as the base total crude. The  $\Delta$  crude elements are derived from the changes in total crude intake for B-A and C-B, respectively. These  $\Delta$  crude changes are then converted to a percent of total crude.

Table III-2 contains a summary of the energy balances for all cases. All elements on this table are expressed in units of F.O.E. liquid barrels. The base energy input consists of total hydrocarbon raw materials plus purchased electric power, adjusted for the energy content changes in by-product out-turn.

Table III-3 contains a summary of the economics for all cases. The format for this table is somewhat different in that all column elements are presented as  $\Delta$  B-A or  $\Delta$  C-B, respectively. The total cost values represent a composite of changes in cost of raw materials, by-product credits, refinery operating expenses and capital charge. The penalties in ¢/barrel are allocated to only the lead-free volumes for the B-A cases, but are distributed over the entire gasoline pool for C-B (lead phase-down).



TABLE III-1  
SUMMARY - CRUDE INTAKE REQUIREMENTS MB/CD

| Case               | 1974        | 1975        | 1976        | 1977        | 1978        | 1979        | 1980        |
|--------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Base Total Crude   | A<br>13,532 | A<br>14,489 | A<br>15,362 | A<br>16,303 | A<br>17,136 | A<br>18,248 | A<br>19,559 |
| 1 Actual           | 0           | 0           | 0           | 0           | 0           | 0           | 0           |
| Δ Crude            | 0           | 0           | 0           | 0           | 0           | 0           | 0           |
| Δ Crude, % of A, B | 0           | 0           | 0           | 0           | 0           | 0           | 0           |
| Base               | 13,493      | 14,460      | 15,375      | 16,303      | 17,134      | 18,248      | 19,565      |
| 1 Actual           | 0           | 0           | 0           | 0           | 0           | 0           | 0           |
| Δ Crude            | 0           | 0           | 0           | 0           | 0           | 0           | 0           |
| Δ Crude, % of A, B | 0           | 0           | 0           | 0           | 0           | 0           | 0           |
| Base               | 13,533      | 14,490      | 15,362      | 16,303      | 17,136      | 18,248      | 19,559      |
| 2 Actual           | (1)         | (1)         | 15          | 48          | 67          | 67          | 67          |
| Δ Crude            | (.01)       | (.01)       | (.09)       | .29         | .39         | .37         | .40         |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |
| Base               |             |             | 15,378      |             |             | 18,248      |             |
| 2 Actual           |             |             | 39          |             |             | 128         |             |
| Δ Crude            |             |             | .25         |             |             | .70         |             |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |
| Base               | 13,532      | 14,496      | 15,847      | 17,064      | 18,347      | 19,709      | 21,247      |
| 3 Actual           | 0           | 0           | 0           | 12          | 46          | (41)        | 101         |
| Δ Crude            | 0           | 0           | 0           | .07         | .25         | (.21)       | .48         |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |
| Base               |             |             | 15,907      |             |             | 19,627      |             |
| 3 Actual           |             |             | (29)        |             |             | 55          |             |
| Δ Crude            |             |             | (.18)       |             |             | .28         |             |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |
| Base               |             |             | 15,362      |             |             | 18,248      |             |
| 4 Actual           |             |             | 0           |             |             | 10          |             |
| Δ Crude            |             |             | 0           |             |             | .05         |             |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |
| Base               |             |             | 13,375      |             |             | 18,248      |             |
| 4 Actual           |             |             | (38)        |             |             | 3           |             |
| Δ Crude            |             |             | (.25)       |             |             | .02         |             |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |
| Base               | 13,517      | 14,496      | 15,396      |             |             |             |             |
| 5 Actual           | 0           | 6           | 8           |             |             |             |             |
| Δ Crude            | 0           | .04         | .05         |             |             |             |             |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |
| Base               | 14,005      | 14,706      | 15,460      |             |             |             |             |
| 6 Actual           | 0           | 0           | 0           |             |             |             |             |
| Δ Crude            | 0           | 0           | 0           |             |             |             |             |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |
| Base               |             |             |             |             |             | 18,245      |             |
| 7 Actual           |             |             |             |             |             | 26          |             |
| Δ Crude            |             |             |             |             |             | .14         |             |
| Δ Crude, % of A, B |             |             |             |             |             |             |             |



SUMMARY ENERGY BALANCES

TABLE 111-2

| Case    | Energy Impact<br>MB/CD (6.3 MB BTU FUEL) | 1974   |     |     | 1975   |     |     | 1976   |      |     | 1977   |       |       | 1978   |       |      | 1979   |      |     | 1980   |     |     |
|---------|------------------------------------------|--------|-----|-----|--------|-----|-----|--------|------|-----|--------|-------|-------|--------|-------|------|--------|------|-----|--------|-----|-----|
|         |                                          | A      | B   | C   | A      | B   | C   | A      | B    | C   | A      | B     | C     | A      | B     | C    | A      | B    | C   | A      | B   | C   |
| 1       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Actual  | Δ Energy Input                           | 12,977 | 0   | 0   | 13,771 | 0   | 0   | 14,483 | 0    | 12  | 15,246 | 13    | 27    | 15,917 | 12    | 34   | 16,823 | 34   | 75  | 17,806 | 69  | 44  |
|         | Δ Energy Input, % of Base                | 0      | 0   | 0   | 0      | 0   | 0   | 0      | 0    | .08 | .09    | .18   | .21   | .08    | .21   | .45  | .20    | .45  | .39 | .39    | .25 |     |
| 1       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Complex | Δ Energy Input, % of Base                | 13,051 | 3   | 0   | 13,842 | 0   | 0   | 14,554 | 7    | 3   | 15,344 | (34)  | (48)  | 16,035 | 5     | 0    | 16,939 | 27   | 17  | 17,924 | 47  | 6   |
|         |                                          | .02    |     |     |        |     |     |        | .05  | .02 |        | (.22) | (.31) | .03    | .03   |      | .16    | .10  | .26 | .26    | .03 |     |
| 2       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Actual  | Δ Energy Input                           | 12,978 | (1) | 5   | 13,772 | (1) | 5   | 14,484 | 13   | 11  | 15,245 | 36    | 26    | 15,917 | 38    | 14   | 16,823 | 77   | 95  | 17,806 | 40  | 20  |
|         | Δ Energy Input, % of Base                | (.01)  |     | .04 | (.01)  |     | .04 |        | .09  | .08 |        | .24   | .17   | .24    | .09   |      | .46    | .56  | .22 | .22    | .11 |     |
| 2       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Complex | Δ Energy Input, % of Base                |        |     |     |        |     |     | 14,585 | (27) | 3   |        |       |       |        |       |      | 16,941 | 27   | 46  |        |     |     |
|         |                                          |        |     |     |        |     |     | (.19)  | .02  |     |        |       |       |        |       |      | .16    | .27  |     |        |     |     |
| 3       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Actual  | Δ Energy Input                           | 12,976 | 0   | 1   | 13,956 | 0   | 1   | 14,918 | 0    | 17  | 15,928 | 11    | 32    | 17,009 | 28    | (98) | 18,139 | (53) | 112 | 19,324 | 72  | 135 |
|         | Δ Energy Input, % of Base                | 0      |     | .01 | 0      |     | .01 |        | 0    | .11 |        | .07   | .20   | .16    | (.58) |      | (.29)  | .62  | .80 | .37    | .80 |     |
| 3       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Complex | Δ Energy Input, % of Base                |        |     |     |        |     |     | 14,968 | 11   | 13  |        |       |       |        |       |      | 18,188 | 24   | 74  |        |     |     |
|         |                                          |        |     |     |        |     |     |        | .07  | .09 |        |       |       |        |       |      | .13    | .41  |     |        |     |     |
| 4       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Actual  | Δ Energy Input                           |        |     |     |        |     |     | 14,483 | 0    | 18  |        |       |       |        |       |      | 16,821 | 10   | 111 |        |     |     |
|         | Δ Energy Input, % of Base                |        |     |     |        |     |     |        | 0    | .12 |        |       |       |        |       |      | .06    | .66  |     |        |     |     |
| 4       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Complex | Δ Energy Input, % of Base                |        |     |     |        |     |     | 14,555 | 14   | 6   |        |       |       |        |       |      | 16,939 | 9    | 41  |        |     |     |
|         |                                          |        |     |     |        |     |     |        | .10  | .04 |        |       |       |        |       |      | .05    | .24  |     |        |     |     |
| 5       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Actual  | Δ Energy Input                           | 13,104 | 0   | 0   | 13,890 | 6   | 0   | 14,646 | 7    | 0   |        |       |       |        |       |      |        |      |     |        |     |     |
|         | Δ Energy Input, % of Base                | 0      |     |     | .04    |     | 0   |        | .05  | 0   |        |       |       |        |       |      |        |      |     |        |     |     |
| 7       | Base Energy Input                        |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      |        |      |     |        |     |     |
| Actual  | Δ Energy Input                           |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      | 16,823 | 26   | 45  |        |     |     |
|         | Δ Energy Input, % of Base                |        |     |     |        |     |     |        |      |     |        |       |       |        |       |      | .15    | .27  |     |        |     |     |

TABLE III-3

## SUMMARY - ECONOMICS

| Case    |                         | 1974  | 1975  |     | 1976  |     | 1977  |     | 1978  |     | 1979  |     | 1980 |      |
|---------|-------------------------|-------|-------|-----|-------|-----|-------|-----|-------|-----|-------|-----|------|------|
|         |                         | B-A   | B-A   | C-B | B-A   | C-B | B-A   | C-B | B-A   | C-B | B-A   | C-B | B-A  | C-B  |
| 1       | Total Cost \$MM/Day     | (.03) | .01   | 0   | (.05) | .02 | (.06) | .09 | .06   | .14 | .12   | .34 | .33  | .28  |
| Actual  | Gasoline Volume MMB/CD* | 7.0   | 1.1   | 7.3 | 2.3   | 7.6 | 3.5   | 7.9 | 4.3   | 8.2 | 5.4   | 8.5 | 6.4  | 8.9  |
|         | Penalty, c/Bbl.         | (0.4) | .9    | 0   | (2.2) | .3  | (1.7) | 1.1 | 1.4   | 1.7 | 2.2   | 4.0 | 5.2  | 3.1  |
| 1       | Total Cost \$MM/Day     | (.08) | (.01) | 0   | (.02) | 0   | (.04) | .08 | .05   | .13 | .17   | .33 | .43  | .24  |
| Complex | Gasoline Volume MMB/CD  | 7.0   | 1.1   | 7.3 | 2.3   | 7.6 | 3.5   | 7.9 | 4.3   | 8.2 | 5.4   | 8.5 | 6.4  | 8.9  |
|         | Penalty, c/Bbl.         | (1.1) | (.9)  | 0   | (.9)  | 0   | (1.1) | 1.0 | 1.2   | 1.6 | 3.1   | 3.9 | 6.7  | 2.7  |
| 2       | Total Cost \$MM/Day     | (.01) | .07   | .02 | .13   | .06 | .29   | .11 | .37   | .26 | .66   | .44 | 1.11 | .35  |
| Actual  | Gasoline Volume MMB/CD  | 7.0   | 1.1   | 7.3 | 2.3   | 7.6 | 3.5   | 7.9 | 4.3   | 8.2 | 5.4   | 8.5 | 6.4  | 8.9  |
|         | Penalty, c/Bbl.         | (.1)  | 6.4   | .3  | 5.6   | .8  | 8.3   | 1.4 | 8.6   | 3.2 | 12.2  | 5.2 | 17.3 | 3.9  |
| 2       | Total Cost \$MM/Day     |       |       |     | .10   | .08 |       |     |       |     | .77   | .51 |      |      |
| Complex | Gasoline Volume MMB/CD  |       |       |     | 2.3   | 7.6 |       |     |       |     | 5.4   | 8.5 |      |      |
|         | Penalty, c/Bbl.         |       |       |     | 4.3   | 1.1 |       |     |       |     | 14.3  | 6.0 |      |      |
| 3       | Total Cost \$MM/Day     | (.03) | .01   | 0   | (.04) | .02 | (.05) | .13 | (.01) | .23 | .21   | .56 | .42  | 1.17 |
| Actual  | Gasoline Volume MMB/CD  | 7.0   | 1.1   | 7.5 | 2.4   | 8.0 | 3.8   | 8.6 | 4.8   | 3.2 | 6.2   | 9.8 | 7.6  | 10.5 |
|         | Penalty, c/Bbl.         | (.4)  | .9    | 0   | (1.7) | .3  | (1.3) | 1.5 | (.2)  | 2.5 | 3.4   | 5.7 | 5.5  | 11.1 |
| 3       | Total Cost \$MM/Day     |       |       |     | (.04) | .02 |       |     |       |     | .25   | .60 |      |      |
| Complex | Gasoline Volume MMB/CD  |       |       |     | 2.4   | 8.0 |       |     |       |     | 6.2   | 9.8 |      |      |
|         | Penalty, c/Bbl.         |       |       |     | (1.7) | .3  |       |     |       |     | 4.0   | 6.1 |      |      |
| 4       | Total Cost \$MM/Day     |       |       |     | .06   | .03 |       |     |       |     | (.04) | .69 |      |      |
| Actual  | Gasoline Volume MMB/CD  |       |       |     | 1.5   | 7.6 |       |     |       |     | 3.9   | 8.5 |      |      |
|         | Penalty, c/Bbl.         |       |       |     | 4.0   | .4  |       |     |       |     | (1.0) | 8.1 |      |      |
| 4       | Total Cost \$MM/Day     |       |       |     | .06   | .02 |       |     |       |     | (.01) | .77 |      |      |
| Complex | Gasoline Volume MMB/CD  |       |       |     | 1.5   | 7.6 |       |     |       |     | 3.9   | 8.5 |      |      |
|         | Penalty, c/Bbl.         |       |       |     | 4.0   | .3  |       |     |       |     | (.3)  | 9.1 |      |      |
| 5       | Total Cost \$MM/Day     | (.04) | .01   | 0   | .02   | 0   |       |     |       |     |       |     |      |      |
| Actual  | Gasoline Volume MMB/CD  | 7.0   | 1.1   | 7.3 | 2.3   | 0   |       |     |       |     |       |     |      |      |
|         | Penalty, c/Bbl.         | (.6)  | .9    | 0   | .9    | 0   |       |     |       |     |       |     |      |      |
| 7       | Total Cost \$MM/Day     |       |       |     |       |     |       |     |       |     | .36   | .25 |      |      |
| Actual  | Gasoline Volume MMB/CD  |       |       |     |       |     |       |     |       |     | 5.4   | 8.5 |      |      |
|         | Penalty, c/Bbl.         |       |       |     |       |     |       |     |       |     | 6.7   | 2.9 |      |      |

\*Lead-Free Volume used for B-A comparison  
 Total Gasoline Volume used for C-B comparison

### C. Impact of Lead Phase-Down

The several cases discussed in Sections III A and III B were designed to define the impact of lead phase-down regulations on refinery crude oil consumption, refining energy consumption, refinery economics, and refinery flexibility for maximizing either fuel oil or gasoline production. These cases not only included the base case for which the best estimates of gasoline growth, etc., were specified, but also various parametric studies wherein several key assumptions were varied to determine the effects of possible errors in these assumptions. Finally, two types of refining simulation were evaluated. The "actual" refinery represents a series of units typifying a single 100,000 B/D refinery, i.e. one FCC Unit, one hydrocracker, etc., each feeding a common stream. The "complex" refinery, by contrast, comprises a plurality of FCC Units (one feeding sour gas oil and one feeding sweet gas oil), a plurality of coking units, etc. Hence, the complex refinery represents a different simulation of the U.S. refining industry, some refineries of which feed sour gas oil to the FCC Unit, some feeding sweet gas oil, etc. The purpose of the present subsection is to consider all of these effects in order to determine the best projection for the entire U.S. refining industry.

#### a. Refining Industry Crude Oil Consumption

Table III-1 summarizes the crude oil penalties in the entire refining industry due to lead phase-down, as abstracted from Tables V-1 through V-11 and further summarized in Tables V-12 through V-22. The Base Total Crude requirements of Table III-1 are the total imported and domestic crude requirements for Scenario A meeting projected product demands for 1974 through 1980. The other entries represent incremental crude oil requirements due to lead-free gasoline and lead phase-down for Scenarios B and C, respectively.

The trends shown in Table III-1 are directionally as would be expected; for example, increasing the octane of the lead-free gasoline or increasing the rate of growth of gasoline demand increase the crude oil penalty. However, the lack of agreement of the "complex" and the "actual" refinery and the lack of a consistent trend with the parametric studies make relative comparisons difficult. For example, selected entries from Table III-1 are as follows:

|                 | <u>1978 C-B</u> | <u>1979 C-B</u> |
|-----------------|-----------------|-----------------|
| Case 1, Actual  | 62              | 35              |
| Case 1, Complex | 105             | (23)            |
| Case 2, Actual  | 18              | 86              |
| Case 3, Actual  | (109)           | 127             |

Comparing each entry to Case 1, Actual, it is apparent that there is no consistent trend between these studies. This probably reflects a certain inadequacy in the refinery simulation; even though the crude oil penalties are small as a percent of Base Total Crude (see Table III-1), they are large enough to be of interest from the point of view of energy policy making. It is felt that the reasons for this variation can be corrected in subsequent studies.

It is apparent from these entries of Table III-1, however, that the maximum crude oil penalty in any given year is 151,000 B/CD which would be incurred under Case 4. However, a more likely largest penalty is about 105,000 B/CD, reached in Case 1 in 1978. A more appropriate measure of crude penalty is obtained by averaging the penalties over the years 1977-1980, for this reduces the above-discussed variability. These averages, tabulated below, should be recognized to exclude several years of zero penalty, during 1974-1976 when the market penetration of lead-free gasoline is small.

|                 | <u>Average Crude Oil Penalty, 1977-1980</u> |                     |
|-----------------|---------------------------------------------|---------------------|
|                 | <u>Scenario B-A</u>                         | <u>Scenario C-B</u> |
| Case 1, Actual  | 44,000 B/CD                                 | 31,000 B/CD         |
| Case 1, Complex | 43,000 B/CD                                 | 22,000 B/CD         |
| Case 2, Actual  | 75,000 B/CD                                 | 42,000 B/CD         |
| Case 3, Actual  | 30,000 B/CD                                 | 28,000 B/CD         |

The agreement between the "actual" and "complex" refinery simulations is now quite good. Specifically, the penalty for Scenario B relative to Scenario A is about 50,000 B/CD and for Scenario C relative to Scenario B is about 30,000 B/CD. Based upon the results of Case 1, the "complex" versus "actual" refinery simulations are equivalent, so no further distinction between these simulations is necessary. Raising the lead-free gasoline octane to 93/85 RON/MON (Case 2) will approximately double the crude oil penalty relative to Case 1. Varying the rate of growth of gasoline (Case 3) does not cause appreciable changes in crude oil penalty relative to Case 1.

Case 4 (lower rate of introduction of lead-free gasoline) and Case 7 (lower percentage premium in the total pool) of Table III-1 could not be averaged in this fashion, because the simulation was run only in 1979. By comparing the penalty of Case 4 to that of Case 3, Actual, in 1979, it is apparent that the average crude penalty could be as low as about 30,000 B/CD for Case 4. Also, the average crude penalty will be less than 150,000 B/CD. However it would not be expected that the lead-free gasoline percent of the pool would be as low as assumed for

Case 4 in the light of announced automobile and petroleum industry plans. Hence, it is not important to define the Case 4 penalty more precisely than 30-150 MB/CD. Case 7 penalties appear consistent with those of Case 1, and can be taken to be equal to those indicated above.

In examining the entries in Table III-1 for the years 1974-1976, it can be seen that the average penalties are in the range of zero to 5,000 B/CD. Hence, the average crude penalties for all cases may be summarized as:

| <u>Average Crude Penalty</u> |                     |                     |                     |                     |
|------------------------------|---------------------|---------------------|---------------------|---------------------|
| <u>1974-1976</u>             |                     | <u>1977-1980</u>    |                     |                     |
|                              | <u>Scenario B-A</u> | <u>Scenario C-B</u> | <u>Scenario B-A</u> | <u>Scenario C-B</u> |
| Case 1                       | 0                   | 5 MB/CD             | 44 MB/CD            | 27 MB/CD            |
| Case 2                       | 5 MB/CD             | 5 MB/CD             | 75 MB/CD            | 42 MB/CD            |
| Case 3                       | 0                   | 5 MB/CD             | 30 MB/CD            | 28 MB/CD            |
| Case 4                       | (10 MB/CD)          | 10 MB/CD            | 10-50 MB/CD         | 30-150 MB/CD        |
| Case 5                       | 5 MB/CD             | 0                   | -                   | -                   |
| Case 6                       | 0                   | 0                   | -                   | -                   |
| Case 7                       | -                   | -                   | 25-50 MB/CD         | 30-75 MB/CD         |

In considering these penalties, it should be recognized that it is difficult to simulate the refining industry within a precision of 1% of crude run (170 MB/CD), and all of these penalties are much smaller. However, it may be generally concluded from this analysis that the crude oil penalty in 1974-1976 will be essentially zero, due to the low market penetration of lead-free gasoline. For the years 1977-1980 on an average, the penalty will be 30 to 44 MB/CD due to the introduction of lead-free gasoline (but increasing with higher lead-free gasoline octane number), with an additional penalty of approximately 28 MB/CD attributable to the lead phase-down regulation.

#### b. Refining Industry Energy Consumption (FEO Basis)

Refinery energy consumption for the cases considered herein is tabulated in Tables V-33 through V-43. The Total Energy Consumed identified in Table V-33, for example, is the summation of purchased electrical power, refinery fuel consumed, and catalytic cracking coke consumed. Also tabulated is  $\Delta$ TEC, the incremental changes of total energy consumed for Scenario B relative to Scenario A and for Scenario C relative to Scenario B. These



increments represent the increased refinery energy consumption for introducing lead-free gasoline (Scenario B) and the further incremental energy consumption attributable to lead phase-down regulations (Scenario C).

A preliminary survey of Tables V-33 through V-43 indicates that, for all cases considered, the energy penalty is extremely small, particularly considering the limits of accuracy of projection. For example, in Table V-33, Case 1, Scenario B, 1980 (the largest entry in this case) has an indicated incremental energy penalty of 34,000 B/CD, above a total base energy consumption of 1,739,000 B/CD, or less than 2%. Furthermore, the total refinery intake for this case is about 18,000,000 B/CD, thus representing approximately 0.2% energy loss on total intake. In addition, it should be noted that this represents a maximum penalty for the single year of 1980. If the energy penalty is averaged over the years 1974 through 1980 for Tables V-33, V-34, V-35, and V-40 (for which entries are available for every year), an estimate of the energy penalty through the remainder of the decade is obtained:

|                 | Average Energy Consumption Penalty<br>(FOE Basis), 1974-1980 |             |
|-----------------|--------------------------------------------------------------|-------------|
|                 | Scenario B                                                   | Scenario C  |
| Case 1, Actual  | 9,000 B/CD                                                   | 10,000 B/CD |
| Case 1, Complex | 10,000 B/CD                                                  | 15,000 B/CD |
| Case 2, Actual  | 16,000 B/CD                                                  | 12,000 B/CD |
| Case 3, Actual  | 10,000 B/CD                                                  | 15,000 B/CD |

Furthermore, by comparing the energy penalties for the other cases of Tables V-33 through V-43 to those for which averages are reported above, it would appear that an approximate value of 10,000 to 20,000 B/CD would represent the average energy penalty for all cases considered.

The primary conclusion from such an analysis is quite clear: penalties from increased refinery energy consumption due to lead phase-down are negligible. Specifically, the present study has examined two widely different simulations of the refining industry (actual vs. complex) and seven different cases which vary lead-free pool octane, rate of growth of gasoline demand, etc. In no case does the energy penalty exceed 60,000 B/CD, and it is highly likely that the average penalty over the years 1974-1980 is from 10,000 to 20,000 B/CD. In the perspective of total refinery intake, this energy penalty is no more significant than refinery leakage and losses. It is perhaps 10% of the savings achieved by lowering comfort levels in buildings by 2° F, and is less than 10% of offshore California oil production. In

short, increased refining industry energy consumption is not an area of concern in making energy policy decisions regarding lead phase-down regulations.

#### c. Total Refinery Energy Utilization

From an examination of Tables V-1 through V-11, it is apparent that the crude penalties discussed earlier are misleading because the production of lead-free gasoline also produces significant quantities of increasingly valuable LPG as a natural by-product of such refinery operation (see Section VI C for additional discussion of the reasons for this). Hence, incremental crude is consumed to produce a product which may be produced anyway under Scenario A if LPG market pressures accelerate because of diminishing natural gas supplies (see Section IV A for LPG market assumptions). However, full credit cannot be taken for this incremental LPG production because increased refinery energy was required to produce it. Hence, in Table III-2, the base energy input to the refinery was taken to be the total raw material intake plus purchased power, thus representing the total energy available when placed on an F.O.E. basis. This figure was then adjusted by subtracting the LPG production of the refinery, on an F.O.E. basis, which was the only remaining plot limit energy variant from case to case within the Scenarios. The difference in this energy input is also reported in Table III-2 for Scenario B relative to Scenario A and for Scenario C relative to Scenario B.

By comparing Table III-1 and Table III-2, it is apparent that much of the crude penalty is regained for many entries by taking credit for LPG production. Because of variable levels of butane purchases, however, some entries are higher than those of Table III-1. The basic data from which Table III-2 was abstracted is contained in Tables V-33 through V-43.

With the exception of Case 3C, 1980, the net energy penalties shown in Table III-2 are generally well below 100,000 B/CD (F.O.E. basis). Case 3C, 1980, is higher due to high butane purchases with rapid gasoline growth (see Table V-3), markedly increasing total refinery intake. From the point of view of energy penalties, this case is artificially high, because butane pricing made it desirable to buy butanes rather than produce them within the refinery. It is likely that butanes could have been produced at a much lower energy penalty than was incurred by outside purchases.

When the 1977 through 1980 net energy input penalties are averaged in the same fashion as discussed under crude penalties, the following summary statistics are obtained:

Average Net Energy Input Penalty, 1977-1980

|                 | <u>Scenario B-A</u> | <u>Scenario C-B</u> |
|-----------------|---------------------|---------------------|
| Case 1, Actual  | 32                  | 45                  |
| Case 1, Complex | 11                  | (4)                 |
| Case 2, Actual  | 48                  | 39                  |
| Case 3, Actual  | 15                  | 50                  |

It is apparent that the entries in this table are more variable than those of the average crude oil penalty. In general, the lower range of numbers in this table are most likely to be accurate measures of the energy penalty. Specifically, reference to Tables V-33, V-34 and V-35 indicate that little butanes are purchased for the "actual" refinery, which differs from normal refinery practice. However, in the "complex" refinery of Table V-40, considerable butanes are purchased. Hence as the refinery pool octane is increased from Scenarios A to B to C, butanes are produced at increasing levels in the refinery which should then back out purchased butanes. The net result, as abstracted from Tables V-33 and V-40 for Case 1 becomes:

|                        | Actual Refinery, MB/CD<br>1978 |            | Complex Refinery, MB/CD<br>1978 |            |
|------------------------|--------------------------------|------------|---------------------------------|------------|
|                        | <u>Scenario B-A</u>            | <u>C-B</u> | <u>B-A</u>                      | <u>C-B</u> |
| Δ Crude                | 12                             | 55         | 28                              | 93         |
| Δ Purchased<br>Butanes | 0                              | 0          | (23)                            | (92)       |
| Net Intake             | 12                             | 55         | 5                               | 1          |

Since the "actual" refinery purchased no butanes, none could be backed out. This leads to a large net intake for the actual refinery, which translates into a net energy input penalty for the actual refinery which does not have the proper credit for backed out purchased butanes. Hence, all average net energy input penalties for the actual refinery tabulated above are expected to be excessively large, by probably 20 MB/CD.

Arguments based only on zero purchased butanes are oversimplified. Other distortions of average net energy input penalty are due to upper limits on purchased butanes, allowable ranges of LPG production, and other differences in "complex" and "actual" refinery models discussed earlier. Although minor refinements in the simulation will be included in Phase II of

this study, it is highly likely that the net energy input penalty for 92/84 RON/MON will be 10-20,000 B/CD for Scenario B relative to A and 20-30,000 B/CD for Scenario C relative to B. For 93/85 RON/MON unleaded gasoline, Scenario B-A incurs a 20-30,000 B/CD net energy input penalty and Scenario C-B also incurs a 20-30,000 B/CD penalty.

#### d. Refining Industry Cost and Construction

As stated previously, one of the objectives of this study was to determine the effects of the various scenarios and cases on capital investment, economic penalty (gasoline price) and the construction industry. These results are described in some detail in Section VI B. In general the results show:

- The new capital investment required by 1980 is about 8 billion dollars (1974 dollars) for all cases except Case 3 (7% gasoline growth) in which case it is 11.75 billion dollars.
- The difference in capital investment between A, B and C scenarios is small relative to the total new investment. This actual investment delta is very sensitive to parameter variation, and warrants further study in Phase II. However, the conclusion that the delta is small is not sensitive to parameter variation.
- The different lead regulation scenarios, B and C, have essentially the same new construction requirements and differences between them are far outweighed by the construction requirement for new refining capacity.
- The economic penalty is small for all cases and scenarios, but it is also reasonably sensitive to octane number and gasoline growth. The penalty for Case 1 has a maximum of 4.0¢/Bbl (C-B). If the gasoline growth rate increases from 4% (Case 1) to 7% (Case 3), the maximum penalty becomes 5.7¢/Bbl (C-B). If on the other hand the octane number increases from 92/84 to 93/85 RON/MON the maximum penalty (C-B) becomes 5.2¢/Bbl. Similarly, the high octane case also has a relatively larger economic penalty for B-A of 12.5¢/Bbl.

#### e. Refinery Flexibility

Studies of refinery flexibility were made by fixing individual unit capacities at the U.S. average levels (see Section IV A) during the years 1974-1976. Then, gasoline specifications were set at either summer or winter levels, and the refinery model was run at adjusted gasoline and fuel oil prices to maximize gasoline



in the summer and fuel oil in the winter (see Case 6, Section III B). Maximum purchased isobutane availability and normal butane availability were set at 112 MB/CD, 110 MB/CD, and 108 MB/CD for 1974, 1975, and 1976, respectively. Allowable ranges of LPG production in the summer were 364 to 392 MB/CD, 382 to 412 MB/CD, and 402 to 433 MB/CD for 1974, 1975 and 1976, respectively. For the winter, a minimum allowable production level was set at 392 MB/CD, 412 MB/CD and 433 MB/CD for 1974, 1975 and 1976 respectively. All other products, such as petrochemical feedstocks and various jet fuels, were held fixed at levels identified in Section IV A.

Assessments of flexibility for producing either fuel oil or gasoline may be made by comparing the several scenarios within a given year in Tables V-6, V-17 and V-38.

The primary conclusions of the study are obtained by comparing, in Table V-6, the Subtotal Gasoline entries between the scenarios for each year and the Distillate plus fuel oil entries between the scenarios. It is apparent that no loss in flexibility to maximize either gasoline or fuel oil can be associated with either lead-free gasoline introduction (Scenario B) or with lead phase-down (Scenario C). The slight increase in gasoline production with lead phase-down is discussed in Section VI C. Because of product pricing assumptions, the LPG production in the summer and winter were at the minimum allowable levels. In the summer, the purchased butanes were diminished with lead phase-down, due to the increased refinery butane production associated with higher gasoline pool octane (shown on Table V-17). Additional implications of this high pool octane are contained in Section VI C.

Because the refining unit capacities (on percent of crude) were fixed, no difference in capital charges for the several scenarios with a given year are observed. Differences in operating costs are attributable to lead savings between Scenarios B and C and to higher pool octanes between Scenarios B and A.

Total energy consumption (refinery fuel, purchased electrical power, and catalytic cracking coke) is shown in Table V-38. Incremental energy consumption between Scenarios B and A are negligibly small (less than 2,000 B/CD) in these flexibility studies. Energy consumptions for Scenarios C versus B are also very small, reaching a maximum of 22,000 B/CD only in the summer of 1976.

#### f. Petrochemical Feedstocks and Other Products

Numerous other refinery products are of importance in the U.S. refining industry simulation, notably petrochemical feedstocks but also naphtha jet and various specialty products. These were fixed at projected market demands, and were met for all scenarios



and all cases evaluated in this study. Thus, they were effectively given a priority allocation among refinery products. The specific product rates for other refinery products are reported in Table IV-1 and are discussed in the accompanying text. In comparing the entries of Table IV-1 to Tables V-1 through V-43, however, it is important to note that the product streams are split slightly differently in these two sets of tables. As described in the text accompanying Table IV-1, these two entries are consistent and may be readily translated from one to the other. These distinctions were made to allow different interested parties to interpret the results on either basis, since these product outturns are constant for all cases.

#### IV Model Considerations

##### A. INPUT DATA

##### Crude Supply and Product Demands

The refinery raw material and product slates assumed for each year in Case 1, Scenario A are shown in Table IV-1. For other cases, the crude and product slates will vary (e.g. 7% growth in gasoline in Case 3). In all the studies, the domestic crudes and the imported sweet crude were fixed. Imported sour crude and purchased iso and normal butanes (with specified maximum volumes) were varied as required to meet product demands and specifications. All product demands were fixed in accordance with Table IV-1 (with adjustments for the various cases), except the total LPG and the low sulfur fuel oil produced were allowed to vary within ranges, since their markets are primarily supplied by sources other than domestic refining. However, no appreciable variation was observed in the low sulfur fuel oil production in actual computer runs.

The domestic crude production estimated by the F.E.O. was 8974 MB/CD; however, historical levels from B.O.M. data are 9491 MB/CD (1972) and 9235 MB/CD (1973). Hence, to reflect additional incentives to domestic exploration, a domestic crude production of about 9250 MB/CD was used for years 1974-1980. Imported crude then made up the difference between the total crude requirements and domestic production, with primary growth taking place in imported sour crude (imported sweet crude level increased from 1680 MB/CD in 1974 to 2100 MB/CD in 1980). Total crude requirements were determined from total product demand projections, discussed below. Natural gasoline available to the refinery was estimated to be 490 MB/CD in 1974. This was based on 1972 B.O.M. data of 450 MB/CD, which was increased slightly for 1974 to reflect increased production incentives. The available natural gasoline was gradually reduced to 382 MB/CD in 1980 to reflect its expected diminishing production. Purchased natural gas for refinery fuel, based on 1972 B.O.M. figures, was 478 MB/CD; this was increased to 490 MB/CD in 1974 and then reduced each year reaching zero in 1980. Total purchased butanes were restricted to a maximum of 224 MB/CD in 1974, and reduced to 190 MB/CD in 1980. These are consistent with 1972 B.O.M. levels of 233 MB/CD and 1973 levels of 212 MB/CD. Note in Table IV-1, however, that Case 1 Scenario A, did not require any external butane purchases.

TABLE IV-1

INPUT/OUTPUT SUMMARY - MB/CD  
CASE 1: ACTUAL REFINERY - UNRESTRICTED CASES (SCENARIO A)

| Crude                     | 1974                     |                                         |                               |        |        |        |        |        |        |        | Basis For Estimates                                                                                        |
|---------------------------|--------------------------|-----------------------------------------|-------------------------------|--------|--------|--------|--------|--------|--------|--------|------------------------------------------------------------------------------------------------------------|
|                           | F.E.O.<br>Market<br>Est. | ADL<br>Import<br>Est.<br>Based on O.C.J | Net<br>Refinery<br>Production | 1974   | 1975   | 1976   | 1977   | 1978   | 1979   | 1980   |                                                                                                            |
| Production                |                          |                                         | 8,974                         | 9,243  | 9,265  | 9,276  | 9,274  | 9,257  | 9,232  | 9,168  | Held approximately fixed<br>Increased to balance crude oil requirements<br>Based on total product estimate |
| Imports                   |                          |                                         |                               | 4,289  | 5,224  | 6,086  | 7,029  | 7,879  | 9,023  | 10,391 |                                                                                                            |
| Total                     |                          |                                         |                               | 13,532 | 14,489 | 15,362 | 16,303 | 17,136 | 18,255 | 19,559 |                                                                                                            |
| Natural Gasoline          |                          |                                         |                               | 430    | 471    | 448    | 423    | 411    | 398    | 382    |                                                                                                            |
| Purch. Refinery Fuel      |                          |                                         |                               | 490    | 441    | 387    | 325    | 257    | 181    | 0      | Purch. as required up to 224 (1974)<br>to 190 (1980)                                                       |
| Purch. Butenes            |                          |                                         |                               | 0      | 0      | 0      | 0      | 0      | 0      | 0      |                                                                                                            |
| Total Gasoline Production | 7,123                    | 130                                     | 6,993                         | 6,988  | 7,265  | 7,576  | 7,875  | 8,176  | 8,499  | 8,862  | 42%/yr. growth from 1974 estimates                                                                         |
| *Premium                  |                          |                                         |                               | 2,401  | 2,485  | 2,553  | 2,640  | 2,760  | 2,900  | 3,001  |                                                                                                            |
| *Regular                  |                          |                                         |                               | 4,047  | 4,355  | 4,468  | 4,572  | 4,645  | 4,756  | 4,889  |                                                                                                            |
| *Lead Free                |                          |                                         |                               | 140    | 147    | 155    | 163    | 171    | 183    | 172    | 62%/yr. growth from 1974 estimates                                                                         |
| Distillate to Fuel        | 3,283                    | 400                                     | 2,883                         | 2,887  | 3,019  | 3,246  | 3,430  | 3,647  | 3,864  | 4,100  |                                                                                                            |
| Residual Fuel             | 3,186                    | 1,950                                   | 1,236                         | 1,260  | 1,588  | 1,794  | 2,050  | 2,159  | 2,478  | 2,846  |                                                                                                            |
| Keroset                   | 1,038                    | 170                                     | 868                           | 768    | 782    | 797    | 827    | 843    | 858    | 874    | 22%/yr growth                                                                                              |
| Naphlet                   | 381                      | 24                                      | 357                           | 250    | 250    | 250    | 250    | 250    | 250    | 250    |                                                                                                            |
| Total Petrochem Feed      | 409                      | 6                                       | 403                           | 403    | 425    | 449    | 473    | 500    | 529    | 559    |                                                                                                            |
| Distillate                |                          |                                         |                               | 180    | 191    | 202    | 214    | 227    | 241    | 255    | 62%/yr. growth                                                                                             |
| BTX                       |                          |                                         |                               | 140    | 147    | 155    | 163    | 171    | 181    | 191    |                                                                                                            |
| LPG                       |                          |                                         |                               | 83     | 86     | 93     | 99     | 104    | 110    | 117    |                                                                                                            |
| *LPG - LNG to Petrochem   |                          |                                         | 281-312                       | 281    | 294    | 309    | 324    | 342    | 360    | 380    | 52%/yr. growth on total LPG produced                                                                       |
| Other Products            |                          |                                         |                               | 1,222  | 1,248  | 1,255  | 1,267  | 1,290  | 1,314  | 1,301  |                                                                                                            |
| Special Naphthas          |                          |                                         |                               | 222    | 200    | 197    | 194    | 197    | 193    | 198    |                                                                                                            |
| Kerosene                  |                          |                                         |                               | 210    | 221    | 216    | 212    | 223    | 217    | 210    | 0 growth                                                                                                   |
| Like Base Stocks          |                          |                                         |                               | 210    | 221    | 216    | 212    | 223    | 217    | 210    |                                                                                                            |
| Asphalt and Road Oil      |                          |                                         |                               | 490    | 500    | 510    | 528    | 531    | 542    | 554    |                                                                                                            |
| Coke                      |                          |                                         |                               | 210    | 206    | 216    | 212    | 206    | 217    | 210    | 12%/yr. growth                                                                                             |
| Total Products            |                          |                                         |                               | 14,059 | 14,911 | 15,676 | 16,496 | 17,207 | 18,152 | 19,172 |                                                                                                            |
|                           |                          |                                         |                               |        |        |        |        |        |        |        | Summation of individual products                                                                           |

IV-2  
• Varies significantly from Scenario A to B to C

Total gasoline market demand in 1974 was estimated to be 7123 MB/CD. Based on Oil and Gas Journal Data, estimated 1974 imports (without embargo) were 130 MB/CD, requiring refining production of about 7000 MB/CD. For Case 1, a growth rate of 4%/year in total gasoline was assumed. Case 3 is a parametric study in which this growth rate is increased to 7%/year. Long term historical data on gasoline growth indicate a 4% average annual increase, although recent data (post 1970) after emission controls has been about 6%. We expect that the effects of more efficient emission controls, gasoline pricing, and consumer energy awareness will result in post-1974 growth rates of 4%/year or less. As will be discussed later, energy penalties associated with lead-free gasoline become more pronounced as the gasoline growth rates are increased. Demand for individual gasoline grades is set by combining the gasoline grade distribution shown on Table II-1 with the total gasoline production of Table IV-1.

Distillate used as fuel (in contrast to petrochemical feedstock) is determined from the FEO 1974 market demand of 3283 MB/CD, and imports of 400 MB/CD as reported by the Oil and Gas Journal. Growth of distillate is assumed to be 6%/year for all cases and all scenarios, reflecting increased use of distillates in markets suffering natural gas supply limitations. Maximum sulfur level of distillates products is 0.2% wt.

Residual fuel demand estimated by the FEO is 3186 MB/CD, and our 1974 import estimates based on Oil and Gas Journal 1973 data are 1950 MB/CD, resulting in required refinery production requirements of about 1250 MB/CD. The domestic residual fuel production for all cases and all scenarios is projected to grow at a level of 15%/year, reflecting a larger market share at the expense of natural gas and reduced conversion operations in U.S. refining. About 90% of the residual fuel under this category is low-sulfur fuel oil, meeting a .5% sulfur limitation.

Kerosene jet fuel demand in 1974 is estimated by FEO to be 1038 MB/CD, with imports of 170 MB/CD. This leads to a production requirement of 868 MB/CD for 1974. However, B.O.M. figures for 1972 are 680 MB/CD and for 1973 are 720 MB/CD. Hence, the FEO 1974 estimate of 868 MB/CD represents a 20% increase over 1973, which is not typical of industry estimates of 1974 consumption levels, even before jet fuel priority allocations. Hence, an estimate of 768 MB/CD was used for 1974, representing a more reasonable 7% increase over 1973 production. Kerojet growth rate for the remaining years was estimated to be 2%/year, which is lower than the recent historical growth rate of 5-6% and more in line with airline traffic growth projections combined with more efficient fuel usage per passenger-mile.

The naphtha jet demand projections by the FEO in 1974 was 381 MB/CD, with 24 MB/CD of imports (Oil and Gas Journal), resulting in 357 MB/CD of refinery production estimated. By similar reasoning to kerojet

and because of domestic competition for petrochemical naphtha, our refinery output projection was set at 250 MB/CD, with any possible growth in this market expected to be supplied by lower-grade imported naphtha. We assumed a peace-time economy. 1973 domestic production was 180 MB/CD.

Total petrochemical feedstock demands in 1974 projected by the FEO are 409 MB/CD, with import estimates of 6 MB/CD. Hence, the estimated 1974 refinery production level is estimated to be 403 MB/CD. Data for 1972 distillate to petrochemical feedstock from the B.O.M. was 143 MB/CD, whereas 1973 B.O.M. data show 171 MB/CD. Hence, 1974 estimates of distillate to petrochemical feedstocks were taken to be 180 MB/CD. Internal estimates by ADL of BTX production, meeting all benzene, toluene, and xylene demands are 111 MB/CD in 1972 and 130 MB/CD in 1973. Thus, the 1974 estimate was taken to be 140 MB/CD. Also 1972 B.O.M. data shows 100 MB/CD of LPG for chemical use. Reflecting upon increased demand of LPG for fuels, the difference between 403 MB/CD of total petrochemical feedstock, and the 1974 estimates of BTX and petrochemical distillate production (totaling 320 MB/CD) would provide a reasonable estimate of 83 MB/CD for LPG as a petrochemical feedstock for 1974.

Bureau of Mines data for winter of 1972 show about 2.6% of crude run for LPG production. For the summer of 1973, LPG yield to crude was 2.8%, reflecting the high demand and price for LPG last summer. Hence, the refinery was required to produce between 2.6 and 2.8% of LPG on an annual basis (Case 6 required 2.8% minimum for winter operation). On an annual basis, this corresponds to 364 to 395 MB/CD in 1974. In Table IV-1 this range is reported as net refinery LPG production after subtracting LPG allocated to petrochemical (83 MB/CD), or as 281 to 312 MB/CD. All petrochemical feedstocks are subjected to a projected growth rate of 6%/year. Although the recent historical growth rate has been 8%/year, most recent reports indicate this historic growth rate will slow down (e.g. Chemical and Engineering News, March, 1974).

Other products from the refinery are also shown, and the 1974 refinery production estimates are based on B.O.M. data:

|                      | <u>1972</u> | <u>1973</u> |
|----------------------|-------------|-------------|
| Special Naphthas     | 88          | 90          |
| Kerosene             | 216         | 217         |
| Lube Base Stocks     | 195         | 204         |
| Asphalt and Road Oil | 446         | 480         |
| Coke                 | 183         | 185         |

Assumed growth patterns are shown on Table IV-1. The refinery simulation used in this study does not attempt to meet any product specifications on these specialty products, other than normal boiling range targets.



The apparent discontinuities in the year to year product demands for the specialty products is due to rounding of total U.S. production to a modular 100 MB/CD composite refinery. The important point is that production levels within any given year are maintained absolutely constant between scenarios A,B,C which is the purpose of this study.

#### Crude and Product Price Assumptions

The key element in these assumptions is our price projections for delivered Arabian light crude oil. We feel that the U.S. Project Independence will not be achieved over the next decade and that in fact we (and the rest of the world) will largely depend on this particular crude as the marginal supply source. We believe it is unrealistic to insulate U.S. energy supply and associated economics from the rest of the free world. Many other energy studies have used Arabian light crude as the primary reference for setting world price parity levels due to its large reserves, present high production volume and potential for increase in supply.

We used the following methodology to predict Arabian light crude price. We assumed two potential scenarios might exist, each with a 50% probability of occurrence. First is that the present price structure will hold for 1974 escalated 4% per year, thereafter. Second, we assumed a drop in FOB price to \$5.00 a barrel but that this price would then escalate 6% per year. This resulted in a delivered Arabian light crude price of \$7.90 a barrel for 1974 which increases to \$10.05 a barrel in 1980. Most other raw material and product prices were estimated based on these crude values.

In previous studies we have done extensive analyses of offshore refining and transshipment of Arabian light crude oil for low sulfur (.5%) residual fuel oil delivery to the U.S. market. Since this is the most important and marginal source of supply for this product, we feel it will set the competitive market price. These values range from \$8.90 a barrel in 1974 to \$11.65 a barrel in 1980. LPG refinery netback was calculated to be on a heating value parity with the price level for low sulfur residual fuel, adjusted for a "form value" premium. Estimated LPG refinery netbacks varied from \$6.11 per barrel in 1974 to \$7.84 a barrel in 1980. The purchase prices for iso and normal butane were assumed to be consistent with LPG price (since in many cases they are interchangeable) and we assumed refinery purchase prices to be 10¢ a barrel higher than LPG netbacks.

We estimated a composite refinery purchase price for natural gas to be \$.30 a thousand standard cubic feet in 1974, escalating to \$.90 in 1980.

### Composite Refinery Structure

As described above, the crude slate for all runs was fixed in source, with the imported sour being varied in quantity as required to meet product demands. The following crudes were taken to represent the refinery input:

Domestic Sweet -- Louisiana  
Domestic Sour -- West Texas  
Imported Sweet -- Nigerian Medium  
Imported Sour -- Arabian Light

The quantity of domestic crude is shown in Table IV-1, and the ratio of domestic sweet to domestic sour was fixed at 2/1.

This crude mix is felt to be representative of future average U.S. crude slates, and will probably represent PAD I and PAD III district slates if additional low sulfur domestic crude is transported to the East Coast for low sulfur fuel oil stocks. No attempt was made to include Alaskan crudes since they will not become a significant market factor until the end of the decade.

The refinery simulated had all of the major refinery units typically present in large U.S. refineries. In some cases, the size of each unit was selected to be optimum for the particular product slate under evaluation (called unrestricted capacity cases). Since this selection of unit capacities frequently deviated from the average U.S. unit capacities, other cases were run in which capacities were restricted to average values listed in the Oil and Gas Journal (called restricted capacity cases). On the basis of 100 MB/CD of atmospheric distillation, these capacities were restricted to a maximum of:

|                    |            |
|--------------------|------------|
| Catalytic Cracker  | 32.2 MB/CD |
| Catalytic Reformer | 26.6 MB/CD |
| Alkylation         |            |
| (Basis product)    | 5.8 MB/CD  |
| Hydrocracking      | 6.2 MB/CD  |

Comparison of these numbers, when scaled up to total U.S. crude run, to the refinery unit feed rates tabulated under Basic Data will indicate the unit size in the simulation relative to the average U.S. unit size. For the restricted capacity cases, hydrocracking and alkylation were always limiting.

## B. MODEL VALIDATION AND CALIBRATION

There are two components to be considered in the validation of a refinery model. First, there is the validation of the proper functioning of the Linear Program, the associated input/output pricing structure (e.g. Arabian Light crude prices through 1980, LPG pricing through 1980, etc.), and the associated product distribution through 1980. The functioning of the L.P. and the pricing structure have been validated through the large number of studies conducted by ADL for various clients, described in part under "Crude and Product Price Assumptions". Although projections or predictions of the future are always suspect, the most reliable guide is knowledge and insight of the views of a wide spectrum of clients concerned with energy supply and economics. Although time constraints did not permit parametric studies of product pricing assumptions, such studies could be used to further determine the impact of such assumptions on the conclusions of the study. Extensive studies of the effect of various assumptions of product distributions were made during the study (e.g. changes of rate of growth of gasoline demand, gasoline grade distribution, etc.). Since the conclusions of the study were not seriously affected by such assumptions, it may be concluded that the model was quite satisfactorily validated in this dimension.

Second, there is a necessity for validation of the structure and behavior of basic refinery units. The basic yields, costs, and relationship to other units were checked independently by consultants for every unit in the refinery. In addition, parametric studies were conducted by varying the allowable complexity of the refinery, (Actual vs. Complex refinery). Also, parametric studies were conducted by comparing unit sizes of processing units for a completely optimal configuration versus sizes dictated by average capacities for the U.S. as reported in the Oil and Gas Journal. Again, the penalties for low lead gasoline in Case 5 versus Case 1, for example, are not significantly different. However the capital investment is very sensitive to parameter variation. This sensitivity will be further studied and defined in Phase II.

It is desirable that additional parametric studies be conducted to study the effects of further variation in unit capacity limitations, petrochemical feedstock demand assumptions, pricing structure assumptions, crude slate assumptions, etc., particularly on capital investment.

Model calibration, in contrast to model validation, is necessary to ensure that the model faithfully represents the U.S. refining industry in 1974. Obviously, many of the above-discussed validation studies are important in that they indicate which types of calibration

errors are insignificant in their effect on the conclusions of the study. In addition, it is important to determine if the catalytic cracker conversion, the catalytic reformer severity, the gasoline pool octanes, etc., adequately represent the U.S. refinery performance. Since many of these variables do not vary outside acceptable ranges within Scenarios A, B, and C, it is unlikely that major effects on the conclusions of the study will be found by improving this calibration (it may be desirable to check this, however). One major concern in calibration is the pool octane in 1974, Scenario A, which is somewhat higher than other estimates. However, it should be noted there is no completely satisfactory method to measure the average clear pool octanes in the U.S. today, and in fact the level can be adjusted merely by changing reformer severity. The effect of error in this calibration should be no greater than shown by Case 2 versus Case 1 (e.g. an additional 50,000 BPD of crude penalty).

However, in this regard, it is important to note that appropriate model calibration does not mean that the 1974 model performance should necessarily duplicate historical refining data, as implied for example by Ethyl Corporation. First, Bureau of Mines data has shown fairly significant change in such variables as gasoline RVP, lead level, etc. during the last year, and some of these trends will likely continue into 1974. Second, significant changes in product values have taken place in the last 6 months (e.g. fuel oil and LPG prices), and these price changes will probably continue. This will have a pronounced effect on the operation of the highly flexible and resourceful refining industry. For example, enhanced market demand for LPG as a natural gas replacement has led to high LPG pricing and high LPG production, particularly in the summer of 1973. Increased LPG production as a percent of crude will most likely come from higher severity reformer operation, high FCC unit severity, and higher hydrocracking severity (or feed rates). With an economic incentive to produce LPG, it would therefore be highly simplistic to assume the clear pool octane of gasoline will not increase above 1972 levels in 1974. Specifically, high LPG production will likely imply increased high clear octane reformat, high clear octane alkylate from FCC olefins, and high reformer feed and yields from hydrocracker naphtha. To better quantify these effects, parametric studies of LPG production need to be conducted to arrive at the proper refinery calibration.



## V. DETAILED DATA

This section contains detailed LP results of all the runs performed in this study. There are four categories of tables. The first eleven (V - 1 to V - 11) contain Basic Data for each run; the next eleven (V - 12 to V - 22) are entitled Reduced Data; then the next ten tables (V - 23 to V - 32) contain an Economic Summary; and, finally, the last eleven tables (V - 33 to V - 43) contain Energy Balances. The last ten pages of this section contain simplified refinery flow diagrams (Figs. V - 1 to V - 10) for selected key cases.

The format used on the Basic Data tables is relatively straight forward and is somewhat similar to that used in Table II-1 (as discussed in the Introduction Section). The material balance data presented as MB/CD total U.S. were obtained by multiplying the LP results from the modular composite refinery developed for each year by our estimate of total U.S. product out-turn. This results in some minor discontinuity between years for by-products production due to this rounding procedure. However, product out-turns were maintained absolutely constant within each year between scenarios A, B, and C (except as noted for LPG and low-sulfur residual fuel oil) and this is the effect we were trying to measure in this study.

Beneath the Total Product sums in the Basic Data tables, additional information is tabulated for each run. This includes refinery fuel consumption (in fuel oil equivalent barrels of 6.3 M MBTU), purchased electric power (refineries were not allowed to generate power), average lead levels in premium and regular gasoline, and calculated optimum intakes to key refinery processing units. The operating cost presented includes purchased supplies, utilities, and operating/maintenance labor. It does not include the cost of purchased or self-generated refinery fuel. The capital charge is derived by a 20% per year gross margin of total invested capital to provide funds for depreciation, income tax, and return on investment.

The format for the Reduced Data tables (V - 12 to V - 23 ) is readily discernible. Near the bottom of the page, purchased electric power is converted to a fuel oil equivalent as is catalyst coke consumed at the catalytic cracking unit. These are then added to the total refinery fuel consumption to create the total energy consumption in FOE barrels.

On Table V - 12 we have tabulated additional information at the bottom of the table to assist in run interpretation. This includes the average catalytic cracker conversion level for each case, the catalytic reformer severity plus the gasoline pool clear research and motor octane numbers for several key years. We have also tabulated at the bottom of this table, our estimate of petrochemical supply distribution for each year.



The Economic Summary tables adopt a somewhat different format. Here we present delta scenario changes within any given year. Specifically Scenario B minus Scenario A and Scenario C minus Scenario B. There are essentially four elements involved in computing the overall economic penalties. These include: Changes in raw material supply costs; Operating costs; Capital charge; and By-product revenue. The differential elements for each case are tabulated on the economic summary tables and composited into a total cost. When this is divided by the volume of the total gasoline pool, the penalty is expressed in cents /barrel. Of course, one could arbitrarily reassign this penalty over selected portions of the pool. At the bottom of this table is a tabulated investment summary for each case. Here the Case A-Total Cumulative Plant Investments- are tabulated in constant 1974 dollars. The differential in total plant investments for Scenario B and C are than shown under the appropriate Delta columns.

The Energy Balances (Table V - 33 to V - 43) adjust the basic material balance barrel differentials to reflect the differential energy penalties from comparing straight volume changes in intakes/production of volatiles with high sulfur crude oil and low sulfur residual fuel oil which all have different heating values. All intakes and energy out-turn products (LPG, distillate, and residual fuel oil) were converted to FOE barrels in this comparison. Near the bottom of the table, the delta TEC rows represent changes in the total energy consumed between scenarios B - A and C - B respectively. At the very bottom of the table, the total energy input is determined by adding the total changes in raw material in (Delta TRMI) purchase power (delta pP) and LPG production.

CASE 1: ACTUAL REFINERY - UNRESTRICTED CASES

TABLE V-1

BASIC DATA

|                                  | 1974   |        | 1975   |        | 1976   |        | 1977   |        | 1978   |        | 1979   |        | 1980   |        |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                                  | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      |
| Domestic Sweet Crude             | 6,162  | 6,162  | 6,177  | 6,177  | 6,184  | 6,184  | 6,183  | 6,183  | 6,171  | 6,171  | 6,148  | 6,148  | 6,112  | 6,112  |
| Domestic Sour Crude              | 3,081  | 3,081  | 3,086  | 3,086  | 3,092  | 3,092  | 3,091  | 3,091  | 3,086  | 3,086  | 3,074  | 3,074  | 3,056  | 3,056  |
| Imported Sweet Crude             | 1,481  | 1,481  | 1,735  | 1,735  | 1,793  | 1,793  | 1,855  | 1,855  | 1,920  | 1,920  | 1,989  | 1,989  | 2,101  | 2,101  |
| Imported Sour Crude              | 3,489  | 3,489  | 3,489  | 3,489  | 4,293  | 4,293  | 5,174  | 5,174  | 5,959  | 5,959  | 7,076  | 7,076  | 8,290  | 8,290  |
| SUBTOTAL CRUDE                   | 13,532 | 13,532 | 14,489 | 14,489 | 15,362 | 15,362 | 16,303 | 16,303 | 17,136 | 17,136 | 18,245 | 18,245 | 19,559 | 19,559 |
| Natural Gasoline                 | 4,900  | 4,900  | 4,711  | 4,711  | 4,448  | 4,448  | 4,233  | 4,233  | 4,111  | 4,111  | 3,988  | 3,988  | 3,823  | 3,823  |
| Purch. Refinery Fuel             | -      | -      | 441    | 441    | 387    | 387    | 325    | 325    | 257    | 257    | 181    | 181    | -      | -      |
| Isobutane                        | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Normal Butane                    | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| TOTAL INPUT                      | 14,512 | 14,512 | 15,401 | 15,401 | 16,197 | 16,197 | 17,051 | 17,051 | 17,804 | 17,804 | 18,826 | 18,826 | 19,941 | 19,941 |
| Premium Gasoline                 | 2,801  | 2,590  | 2,765  | 2,471  | 2,953  | 2,118  | 3,160  | 1,725  | 3,360  | 1,560  | 3,580  | 1,284  | 3,801  | 974    |
| Regular Gasoline                 | 4,047  | 3,908  | 4,353  | 3,706  | 4,468  | 3,185  | 4,572  | 2,685  | 4,665  | 2,297  | 4,756  | 1,863  | 4,889  | 1,509  |
| Lead Free Gasoline               | 140    | 490    | 147    | 1,088  | 155    | 2,273  | 163    | 3,665  | 171    | 4,319  | 163    | 5,352  | 172    | 6,379  |
| SUBTOTAL GASOLINE                | 6,988  | 6,988  | 7,265  | 7,265  | 7,576  | 7,576  | 7,895  | 7,895  | 8,196  | 8,196  | 8,499  | 8,499  | 8,862  | 8,862  |
| BTX                              | 140    | 140    | 147    | 147    | 155    | 155    | 163    | 163    | 171    | 171    | 181    | 181    | 191    | 191    |
| Naphtha                          | 252    | 252    | 250    | 250    | 247    | 247    | 244    | 244    | 237    | 237    | 235    | 235    | 248    | 248    |
| Kero Jet                         | 868    | 868    | 882    | 882    | 897    | 897    | 927    | 927    | 943    | 943    | 958    | 958    | 974    | 974    |
| Kerosene                         | 210    | 210    | 221    | 221    | 216    | 216    | 212    | 212    | 223    | 223    | 217    | 217    | 210    | 210    |
| Distillates                      | 3,067  | 3,067  | 3,250  | 3,250  | 3,448  | 3,448  | 3,644  | 3,644  | 3,874  | 3,874  | 4,105  | 4,105  | 4,355  | 4,355  |
| High Sulfur Fuel                 | 140    | 140    | 147    | 147    | 155    | 155    | 163    | 163    | 171    | 171    | 181    | 181    | 191    | 191    |
| Lube Base Stocks                 | 210    | 210    | 221    | 221    | 216    | 216    | 212    | 212    | 223    | 223    | 217    | 217    | 210    | 210    |
| Asphalt                          | 490    | 490    | 500    | 500    | 510    | 510    | 521    | 521    | 531    | 531    | 542    | 542    | 554    | 554    |
| Coke                             | 210    | 210    | 206    | 206    | 216    | 216    | 212    | 212    | 206    | 206    | 217    | 217    | 210    | 210    |
| SUBTOTAL FIXED                   | 12,575 | 12,575 | 13,089 | 13,089 | 13,636 | 13,636 | 14,189 | 14,189 | 14,775 | 14,775 | 15,388 | 15,388 | 16,026 | 16,026 |
| LPG                              | 364    | 364    | 382    | 382    | 402    | 402    | 423    | 423    | 446    | 446    | 470    | 470    | 497    | 497    |
| Low Sulfur Fuel                  | 1,120  | 1,120  | 1,441  | 1,441  | 1,639  | 1,639  | 1,887  | 1,887  | 1,988  | 1,988  | 2,297  | 2,297  | 2,655  | 2,655  |
| TOTAL PRODUCTS                   | 14,059 | 14,059 | 14,912 | 14,912 | 15,677 | 15,677 | 16,499 | 16,499 | 17,209 | 17,209 | 18,155 | 18,155 | 19,176 | 19,176 |
| Refinery Fuel Used               | 1,050  | 1,050  | 1,118  | 1,118  | 1,187  | 1,187  | 1,261  | 1,261  | 1,332  | 1,332  | 1,407  | 1,407  | 1,499  | 1,537  |
| Purch. Power - Mtl kWh           | 63     | 63     | 67     | 67     | 71     | 71     | 75     | 75     | 80     | 80     | 83     | 83     | 88     | 88     |
| Lead Level - Premium             | 2.33   | 2.47   | 2.13   | 2.55   | 2.12   | 3.00   | 2.13   | 3.00   | 2.17   | 3.00   | 2.19   | 3.00   | 2.20   | 3.00   |
| - Regular                        | 1.46   | 1.43   | 1.44   | 1.61   | 1.48   | 1.83   | 1.52   | 2.24   | 1.56   | 2.69   | 1.67   | 3.00   | 1.84   | 3.00   |
| - Pool (Lead)                    | 1.82   | 1.84   | 1.71   | 1.99   | 1.73   | 2.33   | 1.77   | 2.54   | 1.82   | 2.82   | 1.89   | 3.00   | 2.00   | 3.00   |
| - Pool (Total)                   | 1.78   | 1.72   | 1.67   | 1.69   | 1.70   | 1.63   | 1.73   | 1.42   | 1.78   | 1.33   | 1.86   | 1.11   | 1.96   | 0.84   |
| Intake - Cat Reform              | 3,732  | 3,732  | 3,871  | 3,871  | 4,029  | 4,029  | 4,216  | 4,216  | 4,390  | 4,390  | 4,617  | 4,617  | 4,861  | 4,861  |
| Cat Crack                        | 2,672  | 2,671  | 2,836  | 2,836  | 3,012  | 3,012  | 3,134  | 3,134  | 3,279  | 3,279  | 3,476  | 3,476  | 3,706  | 3,706  |
| Hydro Crk                        | 1,695  | 1,696  | 1,866  | 1,866  | 1,996  | 1,996  | 2,123  | 2,123  | 2,243  | 2,243  | 2,349  | 2,349  | 2,440  | 2,440  |
| Coking                           | 578    | 578    | 568    | 568    | 597    | 597    | 582    | 582    | 567    | 567    | 559    | 559    | 579    | 579    |
| Alky (Feed)                      | 646    | 646    | 631    | 631    | 724    | 724    | 784    | 784    | 843    | 843    | 872    | 872    | 831    | 831    |
| 82 (MCCRD)                       | 1,604  | 1,605  | 1,646  | 1,647  | 2,093  | 2,092  | 2,431  | 2,431  | 2,671  | 2,671  | 2,756  | 2,756  | 2,850  | 2,850  |
| Desulf (Naphtha)                 | 3,357  | 3,357  | 3,606  | 3,606  | 3,847  | 3,847  | 4,031  | 4,031  | 4,291  | 4,291  | 4,606  | 4,606  | 4,960  | 4,960  |
| (Gas Oil)                        | 644    | 644    | 438    | 438    | 271    | 272    | 88     | 88     | 55     | 55     | 40     | 40     | 50     | 50     |
| (VGO)                            | 373    | 371    | 527    | 527    | 682    | 683    | 796    | 796    | 970    | 970    | 1,136  | 1,136  | 1,334  | 1,334  |
| Operating Cost \$/MM             | 7.10   | 7.07   | 7.80   | 7.81   | 8.64   | 8.59   | 9.54   | 9.37   | 10.46  | 10.26  | 11.50  | 11.17  | 12.71  | 12.20  |
| Capital Charge \$/MM             | 10.49  | 10.49  | 11.92  | 11.92  | 13.47  | 13.47  | 15.16  | 15.13  | 16.84  | 16.80  | 18.72  | 18.61  | 20.84  | 20.85  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| - Premium                        | 40     | 37     | 38     | 34     | 39     | 28     | 40     | 22     | 41     | 19     | 42     | 15     | 43     | 11     |
| - Regular                        | 54     | 56     | 60     | 51     | 51     | 59     | 42     | 58     | 57     | 28     | 56     | 22     | 55     | 17     |
| - Lead Free                      | 2      | 7      | 2      | 15     | 2      | 30     | 44     | 44     | 2      | 53     | 2      | 63     | 2      | 72     |

TABLE V-2

CASE 2: ACTUAL REFINERY - 93/85 RON/MON LEAD FREE OCTANE

## MAJORITY DATA

|                                  | 1974   | 1975   | 1976   | 1977   | 1978   | 1979   | 1980   |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|
| Domestic Sweet Crude             | 6,162  | 6,177  | 6,184  | 6,183  | 6,171  | 6,148  | 6,112  |
| Domestic Sour Crude              | 3,081  | 3,086  | 3,092  | 3,091  | 3,086  | 3,074  | 3,056  |
| Imported Sweet Crude             | 1,681  | 1,735  | 1,733  | 1,735  | 1,735  | 1,735  | 1,735  |
| Imported Sour Crude              | 2,609  | 2,608  | 2,608  | 2,608  | 2,608  | 2,608  | 2,608  |
| SUBTOTAL CRUDE                   | 13,533 | 13,532 | 13,532 | 13,532 | 13,532 | 13,532 | 13,532 |
| Natural Gasoline                 | 490    | 490    | 490    | 490    | 490    | 490    | 490    |
| Purch. Refinery Fuel             | 490    | 490    | 490    | 490    | 490    | 490    | 490    |
| Isobutane                        | 490    | 490    | 490    | 490    | 490    | 490    | 490    |
| Normal Butane                    | 490    | 490    | 490    | 490    | 490    | 490    | 490    |
| TOTAL INPUT                      | 14,513 | 14,512 | 14,512 | 14,512 | 14,512 | 14,512 | 14,512 |
| Premium Gasoline                 | 2,801  | 2,591  | 2,765  | 2,471  | 2,471  | 2,471  | 2,471  |
| Regular Gasoline                 | 4,067  | 3,907  | 4,353  | 3,706  | 3,706  | 3,706  | 3,706  |
| Loss: Fuel Gasoline              | 140    | 490    | 147    | 1,048  | 1,048  | 1,048  | 1,048  |
| BTX                              | 6,988  | 6,988  | 7,265  | 7,265  | 7,265  | 7,265  | 7,265  |
| Naphtha                          | 140    | 140    | 147    | 147    | 147    | 147    | 147    |
| Kero Jet                         | 252    | 252    | 250    | 250    | 250    | 250    | 250    |
| Kerosene                         | 868    | 868    | 882    | 882    | 882    | 882    | 882    |
| Distillates                      | 3,097  | 3,067  | 3,250  | 3,250  | 3,250  | 3,250  | 3,250  |
| High Sulfur Fuel                 | 140    | 140    | 147    | 147    | 147    | 147    | 147    |
| Lube Base Stocks                 | 210    | 210    | 210    | 210    | 210    | 210    | 210    |
| Asphalt                          | 490    | 490    | 490    | 490    | 490    | 490    | 490    |
| Coke                             | 210    | 210    | 210    | 210    | 210    | 210    | 210    |
| SUBTOTAL FIXED                   | 12,575 | 12,575 | 13,089 | 13,089 | 13,089 | 13,089 | 13,089 |
| LPG                              | 364    | 364    | 364    | 364    | 364    | 364    | 364    |
| Low Sulfur Fuel                  | 1,120  | 1,120  | 1,441  | 1,441  | 1,441  | 1,441  | 1,441  |
| TOTAL PRODUCTS                   | 14,059 | 14,059 | 14,912 | 14,912 | 14,912 | 14,912 | 14,912 |
| Refinery Fuel Used               | 1,050  | 1,050  | 1,118  | 1,118  | 1,118  | 1,118  | 1,118  |
| Purch. Power - Mill kWh          | 63     | 63     | 67     | 67     | 67     | 67     | 67     |
| Lead Level - Premium             | 2.33   | 2.58   | 2.13   | 2.88   | 2.59   | 2.59   | 2.59   |
| - Regular                        | 1.45   | 1.45   | 1.44   | 1.62   | 1.61   | 1.61   | 1.61   |
| - Pool (Loaded)                  | 1.81   | 1.90   | 1.71   | 2.12   | 2.00   | 2.00   | 2.00   |
| - Pool (Total)                   | 1.77   | 1.77   | 1.67   | 1.81   | 1.70   | 1.70   | 1.70   |
| Intake - Cat Reform              | 3,730  | 3,732  | 3,868  | 3,871  | 3,861  | 3,861  | 3,861  |
| Cat Crack                        | 2,681  | 2,671  | 2,846  | 2,836  | 2,877  | 2,877  | 2,877  |
| Hydro Crk                        | 1,688  | 1,696  | 1,836  | 1,846  | 1,816  | 1,816  | 1,816  |
| Coking                           | 578    | 578    | 568    | 568    | 568    | 568    | 568    |
| Alky (Prod.)                     | 647    | 647    | 684    | 681    | 691    | 691    | 691    |
| H2 (MSGRD)                       | 1,592  | 1,605  | 1,832  | 1,847  | 1,813  | 1,813  | 1,813  |
| Desulf (Naphtha)                 | 3,358  | 3,357  | 3,606  | 3,606  | 3,609  | 3,609  | 3,609  |
| (Gas Oil)                        | 647    | 644    | 441    | 438    | 452    | 452    | 452    |
| (VGO)                            | 382    | 371    | 537    | 527    | 569    | 569    | 569    |
| Operating Cost \$/MM             | 7.10   | 7.10   | 7.80   | 7.88   | 7.83   | 7.83   | 7.83   |
| Capital Charge \$/MM             | 10.49  | 10.49  | 11.92  | 11.92  | 11.93  | 11.93  | 11.93  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |        |
| - Premium                        | 40     | 37     | 38     | 34     | 34     | 34     | 34     |
| - Regular                        | 58     | 56     | 60     | 51     | 51     | 51     | 51     |
| - Lead Free                      | 2      | 7      | 2      | 15     | 15     | 15     | 15     |

V-4

TABLE V-3  
REFINERY MATERIAL BALANCES MB/C/D  
CASE 3: ACTUAL REFINERY 7% GROWTH GASOLINE DEMAND

BASIC DATA

|                                  | 1974   |        |        | 1975   |        |        | 1976   |        |        | 1977   |        |        | 1978   |        |        | 1979   |        |        | 1980   |        |        |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                                  | A      | B      | C      | A      | B      | C      | A      | B      | C      | A      | B      | C      | A      | B      | C      | A      | B      | C      | A      | B      | C      |
| Domestic Sweet Crude             | 6,162  | 6,162  | 6,177  | 6,177  | 6,177  | 6,184  | 6,184  | 6,184  | 6,184  | 6,183  | 6,183  | 6,183  | 6,171  | 6,171  | 6,171  | 6,148  | 6,148  | 6,148  | 6,112  | 6,112  | 6,112  |
| Domestic Sour Crude              | 3,081  | 3,081  | 3,088  | 3,088  | 3,088  | 3,092  | 3,092  | 3,092  | 3,092  | 3,091  | 3,091  | 3,091  | 3,086  | 3,086  | 3,086  | 3,074  | 3,074  | 3,074  | 3,056  | 3,056  | 3,056  |
| Imported Sweet Crude             | 1,681  | 1,681  | 1,735  | 1,735  | 1,735  | 1,793  | 1,793  | 1,793  | 1,793  | 1,855  | 1,855  | 1,855  | 1,920  | 1,920  | 1,920  | 1,989  | 1,989  | 1,989  | 2,101  | 2,101  | 2,101  |
| Imported Sour Crude              | 2,608  | 2,608  | 3,696  | 3,696  | 3,696  | 4,778  | 4,778  | 4,778  | 4,778  | 5,935  | 5,935  | 5,935  | 7,170  | 7,170  | 7,170  | 8,498  | 8,498  | 8,498  | 9,978  | 10,079 | 10,113 |
| SUBTOTAL CRUDE                   | 13,532 | 13,532 | 14,696 | 14,696 | 14,697 | 15,847 | 15,847 | 15,847 | 15,847 | 17,064 | 17,064 | 17,064 | 18,347 | 18,347 | 18,347 | 19,709 | 19,709 | 19,709 | 21,247 | 21,348 | 21,382 |
| Natural Gasoline                 | 490    | 490    | 471    | 471    | 471    | 448    | 448    | 448    | 448    | 423    | 423    | 423    | 411    | 411    | 411    | 398    | 398    | 398    | 362    | 362    | 362    |
| Purch. Refinery Fuel             | 490    | 490    | 441    | 441    | 441    | 387    | 387    | 387    | 387    | 325    | 325    | 325    | 257    | 257    | 257    | 181    | 181    | 181    | -      | -      | -      |
| Isobutane                        | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Normal Butane                    | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| TOTAL INPUT                      | 14,512 | 14,512 | 15,608 | 15,609 | 15,609 | 16,682 | 16,682 | 16,701 | 16,701 | 17,812 | 17,824 | 17,882 | 19,015 | 19,061 | 19,061 | 20,288 | 20,247 | 20,374 | 21,629 | 21,730 | 21,954 |
| Premium Gasoline                 | 2,801  | 2,590  | 2,838  | 2,544  | 2,544  | 3,123  | 2,242  | 2,242  | 2,242  | 3,417  | 1,871  | 1,871  | 3,771  | 1,748  | 1,748  | 4,123  | 1,483  | 1,483  | 4,507  | 1,146  | 1,146  |
| Regular Gasoline                 | 4,047  | 3,908  | 4,471  | 3,794  | 3,794  | 4,731  | 3,370  | 3,370  | 3,370  | 4,979  | 2,929  | 2,929  | 5,194  | 2,572  | 2,572  | 5,479  | 2,134  | 2,134  | 5,787  | 1,795  | 1,795  |
| Lead Free Gasoline               | 140    | 490    | 147    | 1,118  | 1,118  | 170    | 2,412  | 2,412  | 2,412  | 179    | 3,775  | 3,775  | 189    | 4,834  | 4,834  | 181    | 6,166  | 6,166  | 210    | 7,363  | 7,363  |
| SUBTOTAL GASOLINE                | 6,988  | 6,988  | 7,456  | 7,456  | 7,456  | 8,024  | 8,024  | 8,024  | 8,024  | 8,525  | 8,575  | 8,575  | 9,154  | 9,154  | 9,154  | 9,703  | 9,783  | 9,783  | 10,504 | 10,504 | 10,504 |
| BTX                              | 140    | 140    | 147    | 147    | 147    | 155    | 155    | 155    | 155    | 163    | 163    | 163    | 171    | 171    | 171    | 181    | 181    | 181    | 191    | 191    | 191    |
| Naphtha                          | 252    | 252    | 250    | 250    | 250    | 247    | 247    | 247    | 247    | 244    | 244    | 244    | 237    | 237    | 237    | 253    | 253    | 253    | 248    | 248    | 248    |
| Kerosene                         | 868    | 868    | 882    | 882    | 882    | 897    | 897    | 897    | 897    | 927    | 927    | 927    | 943    | 943    | 943    | 958    | 958    | 958    | 974    | 974    | 974    |
| Distillates                      | 210    | 210    | 221    | 221    | 221    | 216    | 216    | 216    | 216    | 212    | 212    | 212    | 223    | 223    | 223    | 217    | 217    | 217    | 210    | 210    | 210    |
| High Sulfur Fuel                 | 140    | 140    | 147    | 147    | 147    | 135    | 135    | 135    | 135    | 163    | 163    | 163    | 171    | 171    | 171    | 181    | 181    | 181    | 191    | 191    | 191    |
| Lube Base Stocks                 | 210    | 210    | 221    | 221    | 221    | 216    | 216    | 216    | 216    | 228    | 228    | 228    | 223    | 223    | 223    | 235    | 235    | 235    | 229    | 229    | 229    |
| Asphalt                          | 490    | 490    | 500    | 500    | 500    | 510    | 510    | 510    | 510    | 521    | 521    | 521    | 531    | 531    | 531    | 542    | 542    | 542    | 554    | 554    | 554    |
| Coke                             | 210    | 210    | 206    | 206    | 206    | 216    | 216    | 216    | 216    | 212    | 212    | 212    | 206    | 206    | 206    | 217    | 217    | 217    | 210    | 210    | 210    |
| SUBTOTAL FIXED                   | 12,575 | 12,575 | 13,280 | 13,280 | 13,280 | 14,084 | 14,084 | 14,084 | 14,084 | 14,789 | 14,789 | 14,789 | 15,753 | 15,753 | 15,753 | 16,672 | 16,672 | 16,672 | 17,666 | 17,666 | 17,666 |
| LPG                              | 364    | 364    | 382    | 382    | 382    | 402    | 402    | 402    | 402    | 423    | 423    | 423    | 456    | 456    | 456    | 464    | 464    | 464    | 497    | 497    | 497    |
| Low Sulfur Fuel                  | 1,120  | 1,120  | 1,441  | 1,441  | 1,441  | 1,639  | 1,639  | 1,639  | 1,639  | 1,887  | 1,887  | 1,887  | 2,160  | 2,160  | 2,160  | 2,392  | 2,392  | 2,392  | 2,655  | 2,655  | 2,655  |
| TOTAL PRODUCTS                   | 14,059 | 14,059 | 15,103 | 15,103 | 15,103 | 16,125 | 16,125 | 16,125 | 16,125 | 17,099 | 17,099 | 17,132 | 18,377 | 18,393 | 18,393 | 19,337 | 19,475 | 19,475 | 20,818 | 20,856 | 20,856 |
| Refinery Fuel Used               | 1,050  | 1,050  | 1,141  | 1,141  | 1,141  | 1,242  | 1,242  | 1,242  | 1,242  | 1,344  | 1,344  | 1,365  | 1,474  | 1,471  | 1,488  | 1,582  | 1,604  | 1,649  | 1,717  | 1,761  | 1,795  |
| Purch. Power - Mll KWH           | 63     | 63     | 68     | 68     | 68     | 74     | 74     | 74     | 74     | 80     | 80     | 80     | 91     | 89     | 88     | 94     | 96     | 95     | 101    | 104    | 102    |
| Lead Level - Premium             | 2.33   | 2.47   | 2.11   | 2.33   | 2.46   | 2.06   | 2.95   | 2.19   | 2.03   | 3.00   | 1.44   | 2.12   | 3.00   | 1.34   | 2.12   | 2.04   | 3.00   | 1.18   | 2.04   | 3.00   | 1.40   |
| - Regular                        | 1.46   | 1.43   | 1.44   | 1.44   | 1.60   | 1.47   | 1.86   | 1.69   | 1.50   | 2.22   | 1.77   | 1.77   | 1.61   | 2.77   | 1.63   | 1.72   | 3.00   | 1.17   | 1.81   | 3.00   | 1.58   |
| - Pool (Leaded)                  | 1.82   | 1.84   | 1.70   | 1.70   | 1.95   | 1.70   | 2.30   | 1.89   | 1.72   | 2.52   | 1.64   | 1.82   | 2.86   | 1.51   | 1.51   | 1.86   | 3.00   | 1.17   | 1.91   | 3.00   | 1.51   |
| - Pool (Total)                   | 1.78   | 1.72   | 1.67   | 1.68   | 1.65   | 1.67   | 1.61   | 1.32   | 1.68   | 1.41   | 0.92   | 1.68   | 1.35   | 0.7    | 0.7    | 1.82   | 1.11   | 0.43   | 1.87   | 0.84   | 0.42   |
| Intake - Cat Reform              | 3,732  | 3,732  | 3,943  | 3,943  | 3,940  | 4,198  | 4,198  | 4,157  | 4,445  | 4,419  | 4,378  | 4,975  | 4,846  | 4,630  | 5,038  | 5,110  | 4,958  | 5,338  | 5,437  | 5,306  | 5,306  |
| Cat Crack                        | 2,672  | 2,671  | 2,956  | 2,955  | 2,965  | 3,295  | 3,295  | 3,443  | 3,633  | 3,726  | 3,674  | 4,468  | 4,306  | 3,962  | 4,199  | 4,092  | 3,808  | 4,653  | 4,423  | 4,169  | 4,169  |
| Hydro Crk                        | 1,695  | 1,696  | 1,844  | 1,844  | 1,837  | 1,993  | 1,993  | 1,885  | 2,156  | 2,087  | 2,096  | 2,880  | 2,597  | 2,346  | 2,606  | 2,720  | 2,443  | 2,632  | 2,743  | 2,521  | 2,521  |
| Coking                           | 578    | 578    | 568    | 568    | 568    | 597    | 597    | 597    | 582    | 582    | 582    | 567    | 567    | 567    | 599    | 599    | 599    | 579    | 579    | 579    | 579    |
| Alky (Prod.)                     | 646    | 646    | 709    | 709    | 710    | 787    | 787    | 821    | 864    | 885    | 962    | 826    | 902    | 1,027  | 996    | 1,042  | 1,244  | 1,098  | 1,192  | 1,358  | 1,358  |
| B2 (HMSUFD)                      | 1,604  | 1,605  | 1,882  | 1,884  | 1,877  | 2,180  | 2,180  | 2,019  | 2,504  | 2,395  | 2,302  | 3,530  | 3,128  | 2,690  | 3,394  | 3,351  | 2,772  | 3,686  | 3,514  | 3,058  | 3,058  |
| Desulf (Naphtha)                 | 3,357  | 3,357  | 3,661  | 3,661  | 3,661  | 3,973  | 3,973  | 3,986  | 4,292  | 4,300  | 4,321  | 4,579  | 4,609  | 4,46   | 4,971  | 4,962  | 5,023  | 5,378  | 5,413  | 5,443  | 5,443  |
| (Gas Oil)                        | 644    | 644    | 649    | 649    | 649    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    | 666    |
| (VGO)                            | 373    | 371    | 649    | 649    | 657    | 966    | 966    | 1,118  | 1,303  | 1,396  | 1,342  | 1,113  | 1,478  | 1,611  | 2,123  | 1,894  | 1,495  | 2,842  | 2,368  | 2,002  | 2,002  |
| Operating Cost \$/MB             | 7.10   | 7.07   | 7.96   | 7.97   | 7.96   | 9.03   | 8.99   | 8.85   | 10.17  | 10.01  | 9.80   | 11.62  | 11.36  | 10.97  | 12.99  | 12.63  | 12.20  | 14.64  | 14.12  | 13.78  | 13.78  |
| Capital Cost \$/MB               | 10.49  | 10.49  | 12.16  | 12.16  | 12.16  | 14.05  | 14.05  | 14.05  | 16.09  | 16.09  | 16.14  | 18.70  | 18.64  | 18.43  | 21.99  | 21.63  | 20.88  | 23.86  | 24.06  | 23.73  | 23.73  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| - Premium                        | 40     | 37     | 38     | 34     | 34     | 39     | 28     | 28     | 40     | 22     | 22     | 22     | 41     | 19     | 19     | 42     | 15     | 15     | 43     | 11     | 11     |
| - Regular                        | 58     | 56     | 60     | 51     | 51     | 59     | 42     | 42     | 58     | 34     | 34     | 34     | 57     | 28     | 28     | 56     | 22     | 22     | 55     | 17     | 17     |
| - Lead Free                      | 2      | 7      | 2      | 15     | 15     | 2      | 30     | 30     | 2      | 44     | 44     | 44     | 2      | 53     | 53     | 2      | 63     | 63     | 2      | 72     | 72     |



TABLE V-4  
CASE 4: ACTUAL REFINERY - REDUCED LEAD FREE DEMANDS

| BASIC DATA                       | 1976   |        |        | 1979   |        |        |
|----------------------------------|--------|--------|--------|--------|--------|--------|
|                                  | A      | B      | C      | A      | B      | C      |
| Domestic Sweet Crude             | 6,184  | 6,184  | 6,184  | 6,148  | 6,148  | 6,148  |
| Domestic Sour Crude              | 3,092  | 3,092  | 3,092  | 3,074  | 3,074  | 3,074  |
| Imported Sweet Crude             | 1,793  | 1,793  | 1,793  | 1,989  | 1,989  | 1,989  |
| Imported Sour Crude              | 4,293  | 4,293  | 4,316  | 7,034  | 7,044  | 7,195  |
| SUBTOTAL CRUDE                   | 15,362 | 15,362 | 15,385 | 18,245 | 18,255 | 18,406 |
| Natural Gasoline                 | 448    | 448    | 448    | 398    | 398    | 398    |
| Purch. Refinery Fuel             | 387    | 387    | 387    | 181    | 181    | 181    |
| Isobutane                        | -      | -      | -      | -      | -      | -      |
| Normal Butane                    | -      | -      | -      | -      | -      | -      |
| TOTAL INPUT                      | 16,197 | 16,197 | 16,220 | 18,824 | 18,834 | 18,985 |
| Premium Gasoline                 | 2,953  | 2,659  | 2,659  | 3,580  | 1,953  | 1,953  |
| Regular Gasoline                 | 4,468  | 3,402  | 3,402  | 4,756  | 2,640  | 2,640  |
| Lead Free Gasoline               | 155    | 1,515  | 1,515  | 163    | 3,906  | 3,906  |
| SUBTOTAL GASOLINE                | 7,576  | 7,576  | 7,576  | 8,499  | 8,499  | 8,499  |
| BTX                              | 155    | 155    | 155    | 181    | 181    | 181    |
| Naphtha                          | 247    | 247    | 247    | 253    | 253    | 253    |
| Kero Jet                         | 897    | 897    | 897    | 958    | 958    | 958    |
| Kerosene                         | 216    | 216    | 216    | 217    | 217    | 217    |
| Distillates                      | 3,448  | 3,448  | 3,448  | 4,105  | 4,105  | 4,105  |
| High Sulfur Fuel                 | 155    | 155    | 155    | 181    | 181    | 181    |
| Lube Base Stocks                 | 216    | 216    | 216    | 235    | 235    | 235    |
| Asphalt                          | 510    | 510    | 510    | 542    | 542    | 542    |
| Coke                             | 216    | 216    | 216    | 217    | 217    | 217    |
| SUBTOTAL, FIXED                  | 13,636 | 13,636 | 13,636 | 15,388 | 15,388 | 15,388 |
| LPG                              | 402    | 402    | 402    | 470    | 470    | 506    |
| Low Sulfur Fuel                  | 1,639  | 1,639  | 1,639  | 2,297  | 2,297  | 2,297  |
| TOTAL PRODUCTS                   | 15,677 | 15,677 | 15,677 | 18,155 | 18,155 | 18,191 |
| Refinery Fuel Used               | 1,187  | 1,187  | 1,189  | 1,407  | 1,409  | 1,456  |
| Purchase Power - Mil KWH         | 71     | 71     | 70     | 83     | 84     | 83     |
| Lead Level - Premium             | 2.12   | 2.79   | 1.77   | 2.19   | 3.00   | .74    |
| - Regular                        | 1.48   | 1.81   | 1.73   | 1.67   | 2.60   | 1.06   |
| -Pool (Leaded)                   | 1.73   | 2.24   | 1.75   | 1.89   | 2.77   | 0.92   |
| -Pool (Total)                    | 1.70   | 1.79   | 1.40   | 1.86   | 1.50   | 0.50   |
| Intake - Cat Reform              | 4,029  | 4,029  | 3,981  | 4,617  | 4,595  | 4,467  |
| Cat Crack                        | 3,012  | 3,012  | 3,193  | 3,374  | 3,481  | 3,409  |
| Hydro Crk                        | 1,996  | 1,996  | 1,865  | 2,349  | 2,311  | 2,061  |
| Coking                           | 597    | 597    | 597    | 599    | 599    | 599    |
| Alky (Prod.)                     | 724    | 724    | 765    | 807    | 830    | 1,038  |
| H2 (MMSCFD)                      | 2,093  | 2,093  | 1,917  | 2,756  | 2,664  | 2,092  |
| Desulf (Naphtha)                 | 3,845  | 3,845  | 3,861  | 4,606  | 4,611  | 4,678  |
| (Gas Oil)                        | 271    | 271    | 322    | 255    | 237    | 474    |
| (VGO)                            | 682    | 682    | 864    | 1,193  | 1,271  | 870    |
| Operating Cost \$MM              | 8.64   | 8.70   | 8.52   | 11.50  | 11.32  | 10.89  |
| Capital Charge \$MM              | 13.47  | 13.47  | 13.48  | 18.72  | 18.76  | 18.69  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |
| -Premium                         | 39     | 35     | 35     | 42     | 23     | 23     |
| -Regular                         | 59     | 45     | 45     | 56     | 31     | 31     |
| -Lead Free                       | 2      | 20     | 20     | 2      | 46     | 46     |



TABLE V-5

REFINERY MATERIAL BALANCES MB/CD  
CASE 5: ACTUAL REFINERY - RESTRICTED REFINING CAPACITY

## BASIC DATA

|                                  | 1974   |        | 1975   |        |        | 1976   |        |        |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
|                                  | A      | B      | A      | B      | C      | A      | B      | C      |
| Domestic Sweet Crude             | 6,162  | 6,162  | 6,177  | 6,177  | 6,177  | 6,184  | 6,184  | 6,184  |
| Domestic Sour Crude              | 3,081  | 3,081  | 3,088  | 3,088  | 3,088  | 3,092  | 3,092  | 3,092  |
| Imported Sweet Crude             | 1,681  | 1,681  | 1,735  | 1,735  | 1,735  | 1,793  | 1,793  | 1,793  |
| Imported Sour Crude              | 2,593  | 2,593  | 3,496  | 3,502  | 3,502  | 4,327  | 4,335  | 4,335  |
| SUBTOTAL CRUDE                   | 13,517 | 13,517 | 14,496 | 14,502 | 14,502 | 15,396 | 15,404 | 15,404 |
| Natural Gasoline                 | 490    | 490    | 471    | 471    | 471    | 448    | 448    | 448    |
| Purch. Refinery Fuel             | 490    | 490    | 441    | 441    | 441    | 387    | 387    | 387    |
| Isobutane                        | 112    | 112    | 110    | 110    | 110    | 108    | 108    | 108    |
| Normal Butane                    | 112    | 112    | 110    | 110    | 110    | 108    | 108    | 108    |
| TOTAL INPUT                      | 14,721 | 14,721 | 15,628 | 15,634 | 15,634 | 16,447 | 16,455 | 16,455 |
| BTX                              | 140    | 140    | 147    | 147    | 147    | 155    | 155    | 155    |
| Naphtha                          | 252    | 252    | 250    | 250    | 250    | 247    | 247    | 247    |
| Kero Jet                         | 868    | 868    | 882    | 882    | 882    | 897    | 897    | 897    |
| Kerosene                         | 210    | 210    | 221    | 221    | 221    | 216    | 216    | 216    |
| High Sulfur Fuel                 | 140    | 140    | 147    | 147    | 147    | 155    | 155    | 155    |
| Lube Base Stocks                 | 210    | 210    | 221    | 221    | 221    | 216    | 216    | 216    |
| Asphalt                          | 490    | 490    | 500    | 500    | 500    | 510    | 510    | 510    |
| Coke                             | 210    | 210    | 206    | 206    | 206    | 216    | 216    | 216    |
| SUBTOTAL FIXED                   | 2,520  | 2,520  | 2,574  | 2,574  | 2,574  | 2,612  | 2,612  | 2,612  |
| Premium Gasoline                 | 2,801  | 2,590  | 2,765  | 2,471  | 2,471  | 2,953  | 2,118  | 2,118  |
| Regular Gasoline                 | 4,047  | 3,908  | 4,353  | 3,706  | 3,706  | 4,468  | 3,185  | 3,185  |
| Lead Free Gasoline               | 140    | 490    | 147    | 1,088  | 1,088  | 155    | 2,273  | 2,273  |
| SUBTOTAL GASOLINE                | 6,988  | 6,988  | 7,265  | 7,265  | 7,265  | 7,576  | 7,576  | 7,576  |
| Distillates                      | 3,067  | 3,067  | 3,250  | 3,250  | 3,250  | 3,448  | 3,448  | 3,448  |
| Low Sulfur Fuel                  | 1,120  | 1,120  | 1,441  | 1,441  | 1,441  | 1,639  | 1,639  | 1,639  |
| LPG                              | 364    | 364    | 382    | 382    | 382    | 402    | 402    | 402    |
| TOTAL PRODUCTS                   | 14,059 | 14,059 | 14,912 | 14,912 | 14,912 | 15,677 | 15,677 | 15,677 |
| Refinery Fuel Used               | 1,055  | 1,055  | 1,116  | 1,125  | 1,125  | 1,189  | 1,200  | 1,200  |
| Purch. Power - Mil KWH           | 56     | 56     | 59     | 59     | 59     | 63     | 63     | 63     |
| Lead Level - Premium             | 1.26   | 1.34   | 1.28   | 1.52   | 1.52   | 1.27   | 1.81   | 1.81   |
| - Regular                        | 1.37   | 1.32   | 1.23   | 1.39   | 1.39   | 1.24   | 1.79   | 1.79   |
| -Pool (Leaded)                   | 1.33   | 1.33   | 1.45   | 1.44   | 1.44   | 1.25   | 1.80   | 1.80   |
| -Pool (Total)                    | 1.30   | 1.23   | 1.22   | 1.23   | 1.23   | 1.23   | 1.26   | 1.26   |
| Intake - Cat Reform              | 3,252  | 3,251  | 3,362  | 3,393  | 3,393  | 3,482  | 3,530  | 3,530  |
| Cat Crack                        | 3,290  | 3,291  | 3,443  | 3,388  | 3,388  | 3,664  | 3,565  | 3,565  |
| Hydro Crack                      | 875    | 875    | 928    | 925    | 925    | 983    | 980    | 980    |
| Coking                           | 578    | 578    | 568    | 568    | 568    | 597    | 597    | 597    |
| Alky (Prod.)                     | 812    | 812    | 853    | 853    | 853    | 897    | 897    | 897    |
| H <sub>2</sub> (MMSCFD)          | 535    | 531    | 650    | 627    | 627    | 772    | 741    | 741    |
| Desulf (Naphtha)                 | 3,427  | 3,427  | 3,665  | 3,546  | 3,546  | 3,916  | 3,953  | 3,953  |
| (Gas Oil)                        | 823    | 822    | 771    | 825    | 825    | 669    | 770    | 770    |
| (VGO)                            | 997    | 999    | 1,140  | 1,087  | 1,087  | 1,339  | 1,240  | 1,240  |
| Operating Cost \$/MM             | 6.74   | 6.70   | 7.40   | 7.39   | 7.39   | 8.19   | 8.19   | 8.19   |
| Capital Charge \$/MM             | 10.01  | 10.01  | 11.35  | 11.32  | 11.32  | 12.80  | 12.75  | 12.75  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |        |        |
| -Premium                         | 40     | 37     | 38     | 34     | 34     | 39     | 28     | 28     |
| -Regular                         | 58     | 56     | 60     | 51     | 51     | 59     | 42     | 42     |
| -Lead Free                       | 2      | 7      | 2      | 15     | 15     | 2      | 30     | 30     |

TABLE V-6

CASE 6: ACTUAL REFINERY - RESTRICTED CAPACITIES, FLEXIBILITY STUDIES

|                                  | SUMMER (9.5 RVP) |        |        |        | WINTER (.12 RVP) |        |        |        |
|----------------------------------|------------------|--------|--------|--------|------------------|--------|--------|--------|
|                                  | 1974             | 1975   | 1976   | 1977   | 1974             | 1975   | 1976   | 1977   |
| <b>BASIC DATA</b>                |                  |        |        |        |                  |        |        |        |
| Domestic Sweet Crude             | 6,162            | 6,177  | 6,184  | 6,184  | 6,162            | 6,177  | 6,184  | 6,184  |
| Domestic Sour Crude              | 3,081            | 3,088  | 3,092  | 3,092  | 3,081            | 3,088  | 3,092  | 3,092  |
| Imported Sweet Crude             | 1,681            | 1,735  | 1,735  | 1,735  | 1,681            | 1,735  | 1,735  | 1,735  |
| Imported Sour Crude              | 3,081            | 3,088  | 3,092  | 3,092  | 3,081            | 3,088  | 3,092  | 3,092  |
| SUBTOTAL CRUDE                   | 14,005           | 14,076 | 14,076 | 14,076 | 14,005           | 14,076 | 14,076 | 14,076 |
| Natural Gasoline                 | 490              | 490    | 490    | 490    | 490              | 490    | 490    | 490    |
| Purch. Refinery Fuel             | 112              | 112    | 112    | 112    | 112              | 112    | 112    | 112    |
| Isobutane                        | 44               | 45     | 45     | 45     | 44               | 45     | 45     | 45     |
| Normal Butane                    | 15,141           | 15,142 | 15,142 | 15,142 | 15,141           | 15,142 | 15,142 | 15,142 |
| TOTAL INPUT                      | 15,141           | 15,142 | 15,142 | 15,142 | 15,141           | 15,142 | 15,142 | 15,142 |
| BTX                              | 140              | 147    | 147    | 147    | 140              | 147    | 147    | 147    |
| Naphtha                          | 252              | 252    | 252    | 252    | 252              | 252    | 252    | 252    |
| Kero Jet                         | 868              | 868    | 868    | 868    | 868              | 868    | 868    | 868    |
| Kerosene                         | 210              | 210    | 210    | 210    | 210              | 210    | 210    | 210    |
| High Sulfur Fuel                 | 140              | 140    | 140    | 140    | 140              | 140    | 140    | 140    |
| Lube Base Stocks                 | 210              | 210    | 210    | 210    | 210              | 210    | 210    | 210    |
| Asphalt                          | 490              | 490    | 490    | 490    | 490              | 490    | 490    | 490    |
| Coke                             | 210              | 210    | 210    | 210    | 210              | 210    | 210    | 210    |
| SUBTOTAL FIXED                   | 2,520            | 2,574  | 2,574  | 2,574  | 2,520            | 2,574  | 2,574  | 2,574  |
| Premium Gasoline                 | 2,832            | 2,832  | 2,832  | 2,832  | 2,832            | 2,832  | 2,832  | 2,832  |
| Regular Gasoline                 | 4,106            | 4,106  | 4,106  | 4,106  | 4,106            | 4,106  | 4,106  | 4,106  |
| Lead Free Gasoline               | 141              | 141    | 141    | 141    | 141              | 141    | 141    | 141    |
| SUBTOTAL GASOLINE                | 7,079            | 7,079  | 7,079  | 7,079  | 7,079            | 7,079  | 7,079  | 7,079  |
| Distillates                      | 3,227            | 3,230  | 3,230  | 3,230  | 3,227            | 3,230  | 3,230  | 3,230  |
| Low Sulfur Fuel                  | 1,249            | 1,249  | 1,249  | 1,249  | 1,249            | 1,249  | 1,249  | 1,249  |
| LPG                              | 364              | 364    | 364    | 364    | 364              | 364    | 364    | 364    |
| TOTAL PRODUCTS                   | 14,439           | 14,440 | 14,440 | 14,440 | 14,439           | 14,440 | 14,440 | 14,440 |
| Refinery Fuel Used               | 1,092            | 1,092  | 1,092  | 1,092  | 1,092            | 1,092  | 1,092  | 1,092  |
| Purch. Power - Mll KWH           | 57               | 58     | 58     | 58     | 57               | 58     | 58     | 58     |
| Lead Level - Premium             | 1.40             | 1.57   | 1.29   | 1.82   | 1.29             | 1.82   | 1.82   | 1.82   |
| - Regular                        | 1.55             | 1.59   | 1.70   | 2.28   | 1.84             | 2.74   | 1.85   | 1.85   |
| - Pool (Lead)                    | 1.49             | 1.58   | 1.54   | 2.07   | 1.62             | 2.51   | 2.00   | 2.00   |
| - Pool (Total)                   | 1.46             | 1.47   | 1.51   | 1.76   | 1.59             | 1.76   | 1.40   | 1.40   |
| Intake - Cat Reform              | 3,167            | 3,181  | 3,222  | 3,250  | 3,222            | 3,250  | 3,272  | 3,272  |
| Cat Crack                        | 3,650            | 3,651  | 3,796  | 3,819  | 3,822            | 4,040  | 4,035  | 3,981  |
| Hydro Crk                        | 894              | 894    | 941    | 952    | 952              | 994    | 1,007  | 1,002  |
| Coking                           | 578              | 578    | 568    | 568    | 568              | 597    | 597    | 597    |
| Alky (Prod.)                     | 812              | 812    | 853    | 853    | 853              | 897    | 897    | 897    |
| H2 (MASCFO)                      | 664              | 655    | 800    | 791    | 777              | 931    | 900    | 799    |
| Desulf (Naphtha)                 | 3,559            | 3,559  | 3,750  | 3,750  | 3,750            | 3,969  | 3,969  | 3,969  |
| Desulf (Gas Oil)                 | 459              | 459    | 415    | 390    | 388              | 289    | 295    | 249    |
| (VGO)                            | 1,361            | 1,361  | 1,497  | 1,522  | 1,524            | 1,721  | 1,715  | 1,661  |
| Operating Cost \$/M              | .03              | .14    | .12    | .12    | .03              | .12    | .12    | .12    |
| Gasoline Grade Distribution - %: |                  |        |        |        |                  |        |        |        |
| - Premium                        | 40               | 40     | 38     | 38     | 39               | 30     | 31     | 31     |
| - Regular                        | 58               | 53     | 60     | 47     | 59               | 40     | 39     | 39     |
| - Lead Free                      | 2                | 7      | 2      | 15     | 2                | 30     | 30     | 30     |

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TABLE V-7

REFINERY MATERIAL BALANCES MB/CD  
CASE 7: ACTUAL REFINERY - REDUCED PREMIUM DEMAND

| BASIC DATA                       | 1979   |        |        |
|----------------------------------|--------|--------|--------|
|                                  | A      | B      | C      |
| Domestic Sweet Crude             | 6,148  | 6,148  | 6,148  |
| Domestic Sour Crude              | 3,074  | 3,074  | 3,074  |
| Imported Sweet Crude             | 1,989  | 1,989  | 1,989  |
| Imported Sour Crude              | 7,034  | 7,060  | 7,135  |
| SUBTOTAL CRUDE                   | 18,245 | 18,271 | 18,346 |
| Natural Gasoline                 | 398    | 398    | 398    |
| Purch. Refinery Fuel             | 181    | 181    | 181    |
| Isobutane                        | -      | -      | -      |
| Normal butane                    | -      | -      | -      |
| TOTAL INPUT                      | 18,824 | 18,850 | 18,925 |
| Premium Gasoline                 | 2,550  | 1,013  | 1,013  |
| Regular Gasoline                 | 5,787  | 2,134  | 2,134  |
| Lead Free Gasoline               | 163    | 5,353  | 5,353  |
| SUBTOTAL GASOLINE                | 8,500  | 8,500  | 8,500  |
| BTX                              | 181    | 181    | 181    |
| Naphtha                          | 253    | 253    | 253    |
| Kerojet                          | 958    | 958    | 958    |
| Kerosene                         | 217    | 217    | 217    |
| Distillates                      | 4,105  | 4,105  | 4,105  |
| High Sulfur Fuel                 | 181    | 181    | 181    |
| Lube Base Stocks                 | 235    | 235    | 235    |
| Asphalt                          | 542    | 542    | 542    |
| Coke                             | 217    | 217    | 217    |
| SUBTOTAL, FIXED                  | 15,389 | 15,389 | 15,389 |
| LPG                              | 470    | 470    | 506    |
| Low Sulfur Fuel                  | 2,297  | 2,297  | 2,297  |
| TOTAL PRODUCTS                   | 18,156 | 18,156 | 18,192 |
| Refinery Fuel Used               | 1,407  | 1,423  | 1,439  |
| Purch. Power - Mll KWH           | 83     | 85     | 85     |
| Lead Level - Premium             | 1.41   | 3.00   | 1.45   |
| Regular                          | 1.34   | 3.00   | 1.30   |
| -Pool (Leaded)                   | 1.36   | 3.00   | 1.35   |
| -Pool (Total)                    | 1.34   | 1.11   | 0.50   |
| Intake - Cat Reform              | 4,617  | 4,665  | 4,599  |
| Cat Crack                        | 3,374  | 3,313  | 3,452  |
| Hydro Crk                        | 2,349  | 2,409  | 2,282  |
| Coking                           | 599    | 599    | 599    |
| Alky (Prod.)                     | 807    | 841    | 926    |
| H <sub>2</sub> (MMSCFD)          | 2,756  | 2,691  | 2,421  |
| Desulf (Naph)                    | 4,606  | 4,615  | 4,647  |
| (Gas Oil)                        | 255    | 315    | 342    |
| (VGO)                            | 1,193  | 1,002  | 1,096  |
| Operating Cost \$MM              | 11.13  | 11.14  | 10.89  |
| Capital Charge \$MM              | 18.72  | 18.82  | 18.87  |
| Gasoline Grade Distribution - %: |        |        |        |
| - Premium                        | 30     | 12     | 12     |
| - Regular                        | 68     | 25     | 25     |
| - Lead Free                      | 2      | 63     | 63     |

TABLE V-8  
REFINERY MATERIAL BALANCES NO/CD  
CASE 1: COMPLEX REFINERY - UNRESTRICTED CASES

|                                  | 1974   |        |        | 1975   |        |        | 1976   |        |        | 1977   |        |        | 1978   |        |        | 1979   |        |        | 1980   |        |  |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|
|                                  | Δ      | Σ      | Δ      | Δ      | Σ      | Δ      | Δ      | Σ      | Δ      | Δ      | Σ      | Δ      | Δ      | Σ      | Δ      | Δ      | Σ      | Δ      | Δ      | Σ      |  |
| Domestic Sweet Crude             | 6,162  | 6,162  | 6,177  | 6,177  | 6,177  | 6,184  | 6,184  | 6,184  | 6,183  | 6,183  | 6,183  | 6,171  | 6,171  | 6,171  | 6,148  | 6,148  | 6,148  | 6,112  | 6,112  | 6,112  |  |
| Domestic Sour Crude              | 3,081  | 3,081  | 3,088  | 3,088  | 3,088  | 3,092  | 3,092  | 3,092  | 3,091  | 3,091  | 3,091  | 3,086  | 3,086  | 3,086  | 3,074  | 3,074  | 3,074  | 3,056  | 3,056  | 3,055  |  |
| Imported Sweet Crude             | 1,681  | 1,681  | 1,735  | 1,735  | 1,735  | 1,793  | 1,793  | 1,793  | 1,855  | 1,855  | 1,855  | 1,920  | 1,920  | 1,920  | 1,989  | 1,989  | 1,989  | 2,101  | 2,101  | 2,101  |  |
| Imported Sour Crude              | 2,569  | 2,569  | 3,460  | 3,460  | 3,460  | 4,306  | 4,306  | 4,306  | 5,176  | 5,176  | 5,176  | 5,957  | 5,957  | 5,957  | 7,037  | 7,037  | 7,037  | 8,296  | 8,296  | 8,295  |  |
| SUBTOTAL CRUDE                   | 13,493 | 13,493 | 16,460 | 16,460 | 16,460 | 15,375 | 15,375 | 15,375 | 16,303 | 16,323 | 16,320 | 17,134 | 17,165 | 17,270 | 18,248 | 18,321 | 18,298 | 19,565 | 19,613 | 19,523 |  |
| Natural Gasoline                 | 490    | 490    | 471    | 471    | 471    | 448    | 448    | 448    | 423    | 423    | 423    | 411    | 411    | 411    | 398    | 398    | 398    | 382    | 382    | 382    |  |
| Purch. Refinery Fuel             | 490    | 490    | 441    | 441    | 441    | 387    | 387    | 387    | 325    | 325    | 325    | 257    | 257    | 257    | 181    | 181    | 181    | 95     | 95     | 95     |  |
| Isobutane                        | 112    | 112    | 110    | 110    | 110    | 94     | 94     | 94     | 78     | 78     | 78     | 66     | 66     | 66     | 55     | 55     | 55     | 45     | 45     | 45     |  |
| Normal Butane                    | 61     | 66     | 47     | 47     | 47     | 7      | 7      | 7      | 58     | 58     | 58     | 94     | 94     | 94     | 99     | 99     | 99     | 95     | 95     | 95     |  |
| TOTAL INPUT                      | 14,646 | 14,651 | 15,530 | 15,530 | 15,530 | 16,312 | 16,327 | 16,321 | 17,215 | 17,156 | 17,182 | 18,001 | 17,999 | 17,967 | 19,017 | 19,034 | 19,075 | 20,136 | 20,164 | 20,193 |  |
| Premium Gasoline                 | 2,801  | 2,590  | 2,765  | 2,471  | 2,471  | 2,953  | 2,118  | 2,118  | 3,160  | 1,725  | 1,725  | 3,360  | 1,560  | 1,560  | 3,580  | 1,284  | 1,284  | 3,801  | 974    | 974    |  |
| Regular Gasoline                 | 4,047  | 3,908  | 4,353  | 3,706  | 3,706  | 4,468  | 3,185  | 3,185  | 4,572  | 2,685  | 2,685  | 4,645  | 2,297  | 2,297  | 4,756  | 1,863  | 1,863  | 4,889  | 1,509  | 1,509  |  |
| Lead Free Gasoline               | 160    | 490    | 167    | 1,088  | 1,088  | 155    | 2,273  | 2,273  | 163    | 3,485  | 3,485  | 171    | 4,319  | 4,319  | 163    | 5,352  | 5,352  | 172    | 6,379  | 6,379  |  |
| SUBTOTAL GASOLINE                | 6,988  | 6,988  | 7,285  | 7,285  | 7,285  | 7,576  | 7,576  | 7,576  | 7,895  | 7,895  | 7,895  | 8,176  | 8,176  | 8,176  | 8,499  | 8,499  | 8,499  | 8,862  | 8,862  | 8,862  |  |
| RTX                              | 160    | 160    | 147    | 147    | 147    | 155    | 155    | 155    | 163    | 163    | 163    | 171    | 171    | 171    | 181    | 181    | 181    | 191    | 191    | 191    |  |
| Naphtha                          | 252    | 252    | 250    | 250    | 250    | 247    | 247    | 247    | 244    | 244    | 244    | 237    | 237    | 237    | 233    | 233    | 233    | 248    | 248    | 248    |  |
| Kero Jet                         | 210    | 210    | 221    | 221    | 221    | 216    | 216    | 216    | 212    | 212    | 212    | 208    | 208    | 208    | 206    | 206    | 206    | 210    | 210    | 210    |  |
| Distillates                      | 3,067  | 3,067  | 3,250  | 3,250  | 3,250  | 3,448  | 3,448  | 3,448  | 3,644  | 3,644  | 3,644  | 3,874  | 3,874  | 3,874  | 4,105  | 4,105  | 4,105  | 4,355  | 4,355  | 4,355  |  |
| High Sulfur Fuel                 | 160    | 160    | 147    | 147    | 147    | 155    | 155    | 155    | 163    | 163    | 163    | 171    | 171    | 171    | 181    | 181    | 181    | 191    | 191    | 191    |  |
| Lube Base Stocks                 | 210    | 210    | 221    | 221    | 221    | 216    | 216    | 216    | 212    | 212    | 212    | 208    | 208    | 208    | 206    | 206    | 206    | 210    | 210    | 210    |  |
| Asphalt                          | 490    | 490    | 500    | 500    | 500    | 510    | 510    | 510    | 521    | 521    | 521    | 531    | 531    | 531    | 542    | 542    | 542    | 554    | 554    | 554    |  |
| Coke                             | 210    | 210    | 206    | 206    | 206    | 216    | 216    | 216    | 212    | 212    | 212    | 208    | 208    | 208    | 206    | 206    | 206    | 210    | 210    | 210    |  |
| SUBTOTAL FIXED                   | 12,575 | 12,575 | 13,089 | 13,089 | 13,089 | 13,636 | 13,636 | 13,636 | 14,189 | 14,189 | 14,189 | 14,775 | 14,775 | 14,775 | 15,388 | 15,388 | 15,388 | 16,024 | 16,024 | 16,024 |  |
| LPG                              | 364    | 364    | 382    | 382    | 382    | 402    | 402    | 402    | 423    | 423    | 423    | 446    | 446    | 446    | 470    | 470    | 469    | 497    | 497    | 505    |  |
| Low Sulfur Fuel                  | 1,120  | 1,120  | 1,441  | 1,441  | 1,441  | 1,639  | 1,639  | 1,639  | 1,887  | 1,887  | 1,887  | 1,988  | 1,988  | 1,988  | 2,297  | 2,297  | 2,297  | 2,655  | 2,655  | 2,655  |  |
| TOTAL PRODUCTS                   | 14,039 | 14,039 | 14,912 | 14,912 | 14,912 | 15,677 | 15,677 | 15,677 | 16,499 | 16,472 | 16,499 | 17,209 | 17,209 | 17,209 | 18,155 | 18,155 | 18,174 | 19,176 | 19,176 | 19,184 |  |
| Refinery Fuel Used               | 1,029  | 1,029  | 1,096  | 1,096  | 1,096  | 1,166  | 1,163  | 1,166  | 1,227  | 1,235  | 1,248  | 1,289  | 1,296  | 1,315  | 1,367  | 1,380  | 1,403  | 1,461  | 1,482  | 1,509  |  |
| Purch. Power - Mtl kWh           | 56     | 56     | 62     | 62     | 62     | 66     | 65     | 66     | 68     | 69     | 70     | 71     | 71     | 74     | 75     | 75     | 78     | 79     | 81     | 83     |  |
| Lead Level - Premium             | 1.83   | 1.77   | 2.03   | 2.40   | 2.40   | 2.12   | 2.93   | 2.49   | 2.03   | 3.00   | 1.71   | 1.83   | 3.00   | 1.52   | 2.05   | 3.00   | 1.34   | 2.07   | 3.00   | 1.42   |  |
| - Regular                        | 1.40   | 1.37   | 1.41   | 1.57   | 1.57   | 1.47   | 1.86   | 1.67   | 1.51   | 2.43   | 1.84   | 1.53   | 2.98   | 1.81   | 1.62   | 3.00   | 1.37   | 1.79   | 3.00   | 2.02   |  |
| - Pool (Leaded)                  | 1.58   | 1.53   | 1.92   | 1.90   | 1.90   | 1.73   | 2.29   | 2.00   | 1.72   | 2.65   | 1.79   | 1.46   | 2.99   | 1.69   | 1.80   | 3.00   | 1.31   | 1.91   | 3.00   | 1.78   |  |
| - Pool (Total)                   | 1.56   | 1.42   | 1.62   | 1.62   | 1.62   | 1.69   | 1.60   | 1.40   | 1.69   | 1.49   | 1.00   | 1.62   | 1.41   | 0.80   | 1.77   | 1.11   | 0.00   | 1.88   | 0.84   | 0.36   |  |
| Intake - Cat Reform              | 3,510  | 3,500  | 3,678  | 3,678  | 3,678  | 3,844  | 3,901  | 3,909  | 4,028  | 4,124  | 4,137  | 4,133  | 4,143  | 4,240  | 4,369  | 4,307  | 4,411  | 4,588  | 4,553  | 4,597  |  |
| Cat Crack                        | 3,133  | 3,161  | 3,196  | 3,196  | 3,196  | 3,199  | 3,272  | 3,304  | 3,506  | 3,371  | 3,464  | 3,782  | 3,812  | 3,756  | 3,814  | 4,110  | 4,154  | 3,906  | 4,337  | 4,425  |  |
| Hydro Crk                        | 1,127  | 1,105  | 1,216  | 1,216  | 1,216  | 1,364  | 1,302  | 1,306  | 1,240  | 1,381  | 1,376  | 1,181  | 1,190  | 1,166  | 1,224  | 1,107  | 1,278  | 1,220  | 1,129  | 1,192  |  |
| Coking                           | 578    | 578    | 568    | 568    | 568    | 597    | 597    | 597    | 582    | 582    | 582    | 567    | 567    | 567    | 559    | 559    | 559    | 579    | 579    | 579    |  |
| Alky (Prod.)                     | 758    | 765    | 772    | 772    | 772    | 775    | 772    | 772    | 848    | 815    | 818    | 915    | 922    | 910    | 929    | 1,090  | 1,013  | 961    | 1,058  | 1,079  |  |
| H2 (WGSF)                        | 763    | 734    | 941    | 941    | 941    | 1,169  | 1,093  | 1,058  | 1,077  | 1,224  | 1,132  | 1,135  | 1,092  | 1,207  | 1,387  | 1,114  | 1,113  | 1,652  | 1,308  | 1,373  |  |
| Desulf (Naphtha)                 | 3,384  | 3,385  | 3,641  | 3,641  | 3,641  | 3,892  | 3,892  | 3,901  | 4,150  | 4,149  | 4,160  | 4,367  | 4,371  | 4,393  | 4,667  | 4,700  | 4,889  | 5,015  | 5,084  | 5,044  |  |
| (Gas Oil)                        | 860    | 864    | 900    | 900    | 900    | 1,022  | 1,010  | 998    | 1,142  | 1,149  | 1,123  | 1,205  | 1,205  | 1,209  | 1,253  | 1,235  | 1,221  | 1,282  | 1,285  | 1,232  |  |
| (VGO)                            | 839    | 867    | 891    | 891    | 891    | 870    | 943    | 940    | 1,173  | 1,036  | 1,131  | 1,539  | 1,544  | 1,404  | 1,911  | 2,056  | 1,863  | 2,422  | 2,523  | 2,466  |  |
| Operating Cost \$/Bbl            | 6.84   | 6.77   | 7.59   | 7.58   | 7.58   | 8.42   | 8.35   | 8.28   | 9.20   | 9.13   | 8.96   | 10.01  | 9.93   | 9.77   | 11.07  | 10.82  | 10.71  | 12.28  | 11.94  | 11.92  |  |
| Capital Charge \$/Bbl            | 11.31  | 11.30  | 12.83  | 12.83  | 12.83  | 14.51  | 14.47  | 14.53  | 16.13  | 16.26  | 16.43  | 17.86  | 17.94  | 18.26  | 19.05  | 20.10  | 20.41  | 22.33  | 22.62  | 22.85  |  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |
| - Premium                        | 40     | 37     | 38     | 34     | 34     | 39     | 28     | 28     | 40     | 22     | 22     | 41     | 19     | 19     | 42     | 15     | 15     | 43     | 11     | 11     |  |
| - Regular                        | 56     | 56     | 60     | 51     | 51     | 59     | 42     | 42     | 58     | 34     | 34     | 57     | 28     | 28     | 56     | 22     | 22     | 55     | 17     | 17     |  |
| - Lead Free                      | 2      | 7      | 2      | 15     | 15     | 2      | 30     | 30     | 2      | 44     | 44     | 2      | 53     | 53     | 2      | 63     | 63     | 2      | 72     | 72     |  |

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TABLE V-9

## REFINERY MATERIAL BALANCES MB/CD

CASE 2: COMPLEX REFINERY 93/85 RON/MON LEAD FREE OCTANE

BASIC DATA

|                                  | 1976   |        |        | 1979   |        |        |
|----------------------------------|--------|--------|--------|--------|--------|--------|
|                                  | A      | B      | C      | A      | B      | C      |
| Domestic Sweet Crude             | 6,184  | 6,184  | 6,184  | 6,148  | 6,148  | 6,148  |
| Domestic Sour Crude              | 3,092  | 3,092  | 3,092  | 3,074  | 3,074  | 3,074  |
| Imported Sweet Crude             | 1,793  | 1,793  | 1,793  | 1,989  | 1,989  | 1,989  |
| Imported Sour Crude              | 4,309  | 4,348  | 4,386  | 7,037  | 7,165  | 7,130  |
| SUBTOTAL CRUDE                   | 15,378 | 15,417 | 15,455 | 18,248 | 18,376 | 18,341 |
| Natural Gasoline                 | 448    | 448    | 448    | 398    | 398    | 398    |
| Purch. Refinery Fuel             | 387    | 387    | 387    | 181    | 181    | 181    |
| Isobutane                        | 92     | 49     | -      | 99     | 56     | 99     |
| Normal Butane                    | 6      | -      | 1      | 93     | -      | 99     |
| TOTAL INPUT                      | 16,311 | 16,301 | 16,291 | 19,019 | 19,011 | 19,118 |
| Premium Gasoline                 | 2,953  | 2,118  | 2,118  | 3,580  | 1,284  | 1,284  |
| Regular Gasoline                 | 4,468  | 3,185  | 3,185  | 4,756  | 1,863  | 1,863  |
| Lead Free Gasoline               | 155    | 2,273  | 2,273  | 163    | 5,352  | 5,352  |
| SUBTOTAL GASOLINE                | 7,576  | 7,576  | 7,576  | 8,499  | 8,499  | 8,499  |
| BTX                              | 155    | 155    | 155    | 181    | 181    | 181    |
| Naphtha                          | 247    | 247    | 247    | 253    | 253    | 253    |
| Kero Jet                         | 897    | 897    | 897    | 958    | 958    | 958    |
| Kerosene                         | 216    | 216    | 216    | 217    | 217    | 217    |
| Distillates                      | 3,448  | 3,448  | 3,448  | 4,105  | 4,105  | 4,105  |
| High Sulfur Fuel                 | 155    | 155    | 155    | 181    | 181    | 181    |
| Lube Base Stocks                 | 216    | 216    | 216    | 235    | 235    | 235    |
| Asphalt                          | 510    | 510    | 510    | 542    | 542    | 542    |
| Coke                             | 216    | 216    | 216    | 217    | 217    | 217    |
| SUBTOTAL FIXED                   | 13,636 | 13,636 | 13,636 | 15,388 | 15,388 | 15,388 |
| LPG                              | 402    | 402    | 402    | 470    | 470    | 506    |
| Low Sulfur Fuel                  | 1,639  | 1,639  | 1,639  | 2,297  | 2,297  | 2,297  |
| TOTAL PRODUCTS                   | 15,677 | 15,677 | 15,677 | 18,155 | 18,155 | 18,191 |
| Refinery Fuel Used               | 1,166  | 1,170  | 1,177  | 1,367  | 1,416  | 1,432  |
| Purch. Power - Mil KWH           | 66     | 67     | 67     | 75     | 78     | 80     |
| Lead Level - Premium             | 2.12   | 3.00   | 2.64   | 2.05   | 3.00   | 1.35   |
| - Regular                        | 1.47   | 1.84   | 1.57   | 1.62   | 3.00   | 1.35   |
| - Pool (Leaded)                  | 1.73   | 2.30   | 2.00   | 1.80   | 3.00   | 1.35   |
| - Pool (Total)                   | 1.69   | 1.61   | 1.40   | 1.77   | 1.11   | 0.50   |
| Intake - Cat Reform              | 3,947  | 3,972  | 3,997  | 4,362  | 4,457  | 4,465  |
| Cat Crack                        | 3,200  | 3,217  | 3,231  | 3,830  | 4,031  | 4,163  |
| Hydro Crk                        | 1,365  | 1,395  | 1,422  | 1,212  | 1,322  | 1,336  |
| Coking                           | 597    | 597    | 597    | 599    | 599    | 599    |
| Alky (Prod.)                     | 775    | 779    | 782    | 935    | 978    | 1,040  |
| H <sub>2</sub> (MMSCFD)          | 1,167  | 1,175  | 1,163  | 1,367  | 1,353  | 1,260  |
| Desulf (Naphtha)                 | 3,893  | 3,902  | 3,915  | 4,669  | 4,703  | 4,700  |
| (Gas Oil)                        | 1,020  | 1,008  | 997    | 1,253  | 1,210  | 1,208  |
| (VGO)                            | 872    | 887    | 903    | 1,922  | 1,863  | 1,816  |
| Operating Cost \$MM              | 8.43   | 8.45   | 8.39   | 11.07  | 11.10  | 10.94  |
| Capital Charge \$MM              | 14.52  | 14.60  | 14.68  | 19.94  | 20.48  | 20.68  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |
| - Premium                        | 39     | 28     | 28     | 42     | 15     | 15     |
| - Regular                        | 59     | 42     | 42     | 56     | 22     | 22     |
| - Lead Free                      | 2      | 30     | 30     | 2      | 63     | 63     |



TABLE V-10 REFINERY MATERIAL BALANCES MB/CD  
CASE 3: COMPLEX REFINERY 7% GROWTH GASOLINE DEMAND

BASIC DATA

|                                  | 1976   |        |        | 1979   |        |        |
|----------------------------------|--------|--------|--------|--------|--------|--------|
|                                  | A      | B      | C      | A      | B      | C      |
| Domestic Sweet Crude             | 6,184  | 6,184  | 6,184  | 6,148  | 6,148  | 6,148  |
| Domestic Sour Crude              | 3,092  | 3,092  | 3,092  | 3,074  | 3,074  | 3,074  |
| Imported Sweet Crude             | 1,793  | 1,793  | 1,793  | 1,989  | 1,989  | 1,989  |
| Imported Sour Crude              | 4,838  | 4,809  | 4,837  | 8,416  | 8,471  | 8,547  |
| SUBTOTAL CRUDE                   | 15,907 | 15,878 | 15,906 | 19,627 | 19,682 | 19,758 |
| Natural Gasoline                 | 448    | 448    | 448    | 398    | 398    | 398    |
| Purch. Refinery Fuel             | 387    | 387    | 387    | 181    | 181    | 181    |
| Isobutane                        | -      | 56     | 14     | 99     | 88     | 99     |
| Normal Butane                    | -      | 2      | 25     | 99     | 99     | 99     |
| TOTAL INPUT                      | 16,742 | 16,771 | 16,780 | 20,404 | 20,448 | 20,535 |
| Premium Gasoline                 | 3,123  | 2,242  | 2,242  | 4,123  | 1,483  | 1,483  |
| Regular Gasoline                 | 4,731  | 3,370  | 3,370  | 5,479  | 2,134  | 2,134  |
| Lead Free Gasoline               | 170    | 2,412  | 2,412  | 181    | 6,166  | 6,166  |
| SUBTOTAL GASOLINE                | 8,024  | 8,024  | 8,024  | 9,783  | 9,783  | 9,783  |
| BTX                              | 155    | 155    | 155    | 181    | 181    | 181    |
| Naphtha                          | 247    | 247    | 247    | 253    | 253    | 253    |
| Kero Jet                         | 897    | 897    | 897    | 958    | 958    | 958    |
| Kerosene                         | 216    | 216    | 216    | 217    | 217    | 217    |
| Distillates                      | 3,448  | 3,448  | 3,448  | 4,105  | 4,105  | 4,105  |
| High Sulfur Fuel                 | 155    | 155    | 155    | 181    | 181    | 181    |
| Lube Base Stocks                 | 216    | 216    | 216    | 235    | 235    | 235    |
| Asphalt                          | 510    | 510    | 510    | 542    | 542    | 542    |
| Coke                             | 216    | 216    | 216    | 217    | 217    | 217    |
| SUBTOTAL FIXED                   | 14,084 | 14,084 | 14,084 | 16,672 | 16,672 | 16,672 |
| LPG                              | 402    | 402    | 402    | 470    | 505    | 506    |
| Low Sulfur Fuel                  | 1,639  | 1,639  | 1,639  | 2,301  | 2,297  | 2,297  |
| TOTAL PRODUCTS                   | 16,125 | 16,125 | 16,125 | 19,443 | 19,474 | 19,475 |
| Refinery Fuel Used               | 1,229  | 1,225  | 1,226  | 1,539  | 1,584  | 1,604  |
| Purch. Power - Mil KWH           | 71     | 70     | 70     | 86     | 88     | 88     |
| Lead Level - Premium             | 2.20   | 3.00   | 2.34   | 1.98   | 3.00   | 1.17   |
| - Regular                        | 1.48   | 1.86   | 1.59   | 1.65   | 3.00   | 1.18   |
| - Pool (Leaded)                  | 1.77   | 2.32   | 1.89   | 1.79   | 3.00   | 1.18   |
| - Pool (Total)                   | 1.73   | 1.62   | 1.32   | 1.76   | 1.11   | 0.43   |
| Intake - Cat Reform              | 4,232  | 4,142  | 4,108  | 4,768  | 4,937  | 4,767  |
| Cat Crack                        | 3,242  | 3,389  | 3,519  | 4,617  | 4,228  | 4,512  |
| Hydro Crk                        | 1,685  | 1,560  | 1,501  | 1,526  | 1,747  | 1,463  |
| Coking                           | 597    | 597    | 597    | 599    | 599    | 599    |
| Alky (Prod.)                     | 785    | 821    | 852    | 1,125  | 1,143  | 1,302  |
| H <sub>2</sub> (MMSCFD)          | 1,636  | 1,480  | 1,357  | 2,107  | 2,246  | 1,770  |
| Desulf (Naphtha)                 | 4,014  | 4,015  | 4,023  | 5,007  | 5,016  | 5,058  |
| (Gas Oil)                        | 915    | 895    | 864    | 1,011  | 1,264  | 1,360  |
| (VGO)                            | 1,789  | 1,062  | 1,194  | 2,600  | 2,051  | 2,257  |
| Operating Cost \$MM              | 8.92   | 8.82   | 8.69   | 12.52  | 12.25  | 11.99  |
| Capital Charge \$MM              | 15.34  | 15.26  | 15.29  | 22.31  | 22.60  | 22.66  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |
| -Premium                         | 39     | 28     | 28     | 42     | 15     | 15     |
| -Regular                         | 59     | 47     | 42     | 56     | 22     | 22     |
| -Lead Free                       | 2      | 30     | 30     | 2      | 63     | 63     |

TABLE V-11

REFINERY MATERIAL BALANCES MB/CD  
CASE 4: COMPLEX REFINERY REDUCED LEAD FREE DEMANDSBASIC DATA

|                                  | 1976   |        |        | 1979   |        |        |
|----------------------------------|--------|--------|--------|--------|--------|--------|
|                                  | A      | B      | C      | A      | B      | C      |
| Domestic Sweet Crude             | 6,184  | 6,184  | 6,184  | 6,148  | 6,148  | 6,148  |
| Domestic Sour Crude              | 3,092  | 3,092  | 3,092  | 3,074  | 3,074  | 3,074  |
| Imported Sweet Crude             | 1,793  | 1,793  | 1,793  | 1,989  | 1,989  | 1,989  |
| Imported Sour Crude              | 4,306  | 4,268  | 4,308  | 7,037  | 7,040  | 7,140  |
| SUBTOTAL CRUDE                   | 15,375 | 15,337 | 15,377 | 18,248 | 18,251 | 18,351 |
| Natural Gasoline                 | 443    | 448    | 448    | 398    | 398    | 398    |
| Purch. Refinery Fuel             | 387    | 387    | 387    | 181    | 181    | 181    |
| Isobutane                        | 94     | 108    | 108    | 99     | 99     | 44     |
| Normal Butane                    | 7      | 69     | 25     | 91     | 99     | 99     |
| TOTAL INPUT                      | 16,312 | 16,349 | 16,345 | 19,017 | 19,028 | 19,073 |
| Premium Gasoline                 | 2,953  | 2,659  | 2,659  | 3,580  | 1,953  | 1,953  |
| Regular Gasoline                 | 4,468  | 3,402  | 3,402  | 4,756  | 2,640  | 2,640  |
| Lead Free Gasoline               | 155    | 1,515  | 1,515  | 163    | 3,906  | 3,906  |
| SUBTOTAL GASOLINE                | 7,576  | 7,576  | 7,576  | 8,499  | 8,499  | 8,499  |
| BTX                              | 155    | 155    | 155    | 181    | 181    | 181    |
| Naphtha                          | 247    | 247    | 247    | 253    | 253    | 253    |
| Kero Jet                         | 897    | 897    | 897    | 958    | 958    | 958    |
| Kerosene                         | 216    | 216    | 216    | 217    | 217    | 217    |
| Distillates                      | 3,448  | 3,448  | 3,448  | 4,105  | 4,105  | 4,105  |
| High Sulfur Fuel                 | 155    | 155    | 155    | 181    | 181    | 181    |
| Lube Base Stocks                 | 216    | 216    | 216    | 235    | 235    | 235    |
| Asphalt                          | 510    | 510    | 510    | 542    | 542    | 542    |
| Coke                             | 216    | 216    | 216    | 217    | 217    | 217    |
| SUBTOTAL FIXED                   | 13,636 | 13,636 | 13,636 | 15,388 | 15,388 | 15,388 |
| LPG                              | 402    | 402    | 402    | 470    | 470    | 503    |
| Low Sulfur Fuel                  | 1,639  | 1,639  | 1,639  | 2,297  | 2,297  | 2,297  |
| TOTAL PRODUCTS                   | 15,677 | 15,677 | 15,677 | 18,155 | 18,155 | 18,188 |
| Refinery Fuel Used               | 1,166  | 1,158  | 1,164  | 1,367  | 1,371  | 1,412  |
| Purch. Power - Mll KWH           | 66     | 64     | 65     | 75     | 75     | 80     |
| Lead Level - Premium             | 2.12   | 2.61   | 1.87   | 2.05   | 3.00   | .64    |
| - Regular                        | 1.47   | 1.78   | 1.66   | 1.62   | 2.89   | 1.13   |
| - Pool (Leaded)                  | 1.73   | 2.14   | 1.75   | 1.80   | 2.94   | 0.92   |
| - Pool (Total)                   | 1.69   | 1.72   | 1.40   | 1.77   | 1.59   | 0.50   |
| Intake - Cat Reform              | 3,944  | 3,827  | 3,839  | 4,369  | 4,344  | 4,488  |
| Cat Crack                        | 3,199  | 3,394  | 3,443  | 3,814  | 3,873  | 4,103  |
| Hydro Crk                        | 1,364  | 1,197  | 1,206  | 1,224  | 1,183  | 1,372  |
| Coking                           | 597    | 597    | 597    | 599    | 599    | 599    |
| Alky (Prod.)                     | 775    | 823    | 833    | 929    | 944    | 993    |
| H <sub>2</sub> (MMSCFD)          | 1,169  | 962    | 965    | 1,387  | 1,318  | 1,336  |
| Desulf (Naphtha)                 | 3,892  | 3,890  | 3,902  | 4,667  | 4,673  | 4,698  |
| (Gas Oil)                        | 1,022  | 991    | 972    | 1,253  | 1,255  | 1,219  |
| (VGO)                            | 870    | 1,067  | 1,118  | 1,911  | 1,953  | 1,788  |
| Operating Cost \$MM              | 8.42   | 8.40   | 8.29   | 11.07  | 10.96  | 10.82  |
| Capital Charge \$MM              | 14.51  | 14.40  | 14.49  | 19.95  | 19.96  | 20.61  |
| Gasoline Grade Distribution - %: |        |        |        |        |        |        |
| - Premium                        | 39     | 35     | 35     | 42     | 23     | 23     |
| - Regular                        | 59     | 45     | 45     | 56     | 31     | 31     |
| - Lead Free                      | 2      | 20     | 20     | 2      | 46     | 46     |

TABLE V-12  
REFINERY MATERIAL BALANCES NO./CD  
CASE 1: ACTUAL REFINERY - UNRESTRICTED CASES

|                           | 1974   |        | 1975   |        | 1976   |        | 1977   |        | 1978   |        | 1979   |        | 1980   |        |
|---------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                           | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      |
| Total Crude Intake        | 13,532 | 13,532 | 16,489 | 16,489 | 15,362 | 15,362 | 16,303 | 16,319 | 17,149 | 17,211 | 18,322 | 18,322 | 19,559 | 19,662 |
| Δ Crude A vs. B/B vs. C   | 51.64  | 51.64  | 50.14  | 50.14  | 49.32  | 49.32  | 48.30  | 48.26  | 47.71  | 47.68  | 46.38  | 46.38  | 45.31  | 45.07  |
| Δ Crude %                 | 48.15  | 48.15  | 47.17  | 47.17  | 46.77  | 46.77  | 46.18  | 46.14  | 45.92  | 45.89  | 45.15  | 45.05  | 44.44  | 44.21  |
| Total Intake              | 14,512 | 14,512 | 15,401 | 15,401 | 16,197 | 16,211 | 17,051 | 17,067 | 17,804 | 17,817 | 18,824 | 18,866 | 19,941 | 20,044 |
| Δ Intake A vs. B/B vs. C  | 8.28   | 8.28   | 9.95   | 9.95   | 10.67  | 10.67  | 11.57  | 11.56  | 11.60  | 11.59  | 12.59  | 12.56  | 13.57  | 13.50  |
| Δ Intake %                | 30.94  | 30.94  | 32.38  | 32.38  | 33.11  | 33.11  | 33.92  | 33.89  | 34.21  | 34.18  | 35.09  | 35.07  | 36.94  | 36.65  |
| Gasoline Production       | 6,988  | 6,988  | 7,265  | 7,265  | 7,576  | 7,576  | 7,875  | 7,875  | 8,176  | 8,176  | 8,499  | 8,499  | 8,862  | 8,862  |
| % Crude Intake            | 51.64  | 51.64  | 50.14  | 50.14  | 49.32  | 49.32  | 48.30  | 48.26  | 47.71  | 47.68  | 46.38  | 46.38  | 45.31  | 45.07  |
| % Total Intake            | 48.15  | 48.15  | 47.17  | 47.17  | 46.77  | 46.77  | 46.18  | 46.14  | 45.92  | 45.89  | 45.15  | 45.05  | 44.44  | 44.21  |
| Distillates - % Crude     | 22.66  | 22.66  | 22.43  | 22.43  | 22.44  | 22.44  | 22.35  | 22.33  | 22.61  | 22.59  | 22.50  | 22.45  | 22.27  | 22.15  |
| Low Sulfur Fuel - % Crude | 8.28   | 8.28   | 9.95   | 9.95   | 10.67  | 10.67  | 11.57  | 11.56  | 11.60  | 11.59  | 12.59  | 12.56  | 13.57  | 13.50  |
| Dist. + LSF - % Crude     | 30.94  | 30.94  | 32.38  | 32.38  | 33.11  | 33.11  | 33.92  | 33.89  | 34.21  | 34.18  | 35.09  | 35.07  | 36.94  | 36.65  |
| LPG - % Crude             | 2.69   | 2.69   | 2.64   | 2.64   | 2.62   | 2.62   | 2.59   | 2.59   | 2.60   | 2.60   | 2.58   | 2.60   | 2.54   | 2.72   |
| Total Product Outturn     | 14,059 | 14,059 | 16,912 | 16,912 | 15,677 | 15,677 | 16,499 | 16,499 | 17,209 | 17,209 | 18,155 | 18,161 | 19,176 | 19,216 |
| Δ Outturn A vs. B/B vs. C | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Outturn %               | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Intake - Outturn          | 453    | 453    | 449    | 449    | 520    | 520    | 552    | 568    | 595    | 608    | 669    | 705    | 765    | 830    |
| Δ A vs. B/B vs. C         | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ % Crude                 | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Total Refinery Fuel       | 1,050  | 1,050  | 1,118  | 1,118  | 1,187  | 1,187  | 1,261  | 1,261  | 1,329  | 1,332  | 1,407  | 1,423  | 1,499  | 1,530  |
| % Crude Intake            | 7.76   | 7.76   | 7.72   | 7.72   | 7.73   | 7.73   | 7.73   | 7.73   | 7.76   | 7.77   | 7.71   | 7.78   | 7.66   | 7.78   |
| Purchased Power - F.O.E.  | 100    | 100    | 106    | 106    | 113    | 113    | 119    | 119    | 127    | 127    | 132    | 133    | 140    | 141    |
| Cat Crack Coke F.O.E.     | 77     | 77     | 81     | 81     | 86     | 86     | 90     | 94     | 94     | 98     | 97     | 98     | 100    | 102    |
| Energy Consumed           | 1,227  | 1,227  | 1,305  | 1,305  | 1,386  | 1,386  | 1,470  | 1,476  | 1,550  | 1,557  | 1,636  | 1,654  | 1,739  | 1,773  |
| % Crude Intake            | 9.07   | 9.07   | 9.01   | 9.01   | 9.02   | 9.02   | 9.02   | 9.03   | 9.05   | 9.08   | 8.97   | 9.04   | 8.89   | 9.02   |
| Cat Crk Conv - IV         | 65     | 65     | 65     | 65     | 65     | 65     | 65     | 65     | 65     | 65     | 65     | 68     | 65     | 72     |
| Reformer R-O              | 91     | 91     | 91     | 91     | 91     | 91     | 91     | 91     | 91     | 91     | 92     | 95     | 97     | 97     |
| Gas Pool R-O              | 89.4   | 89.4   | 89.4   | 89.4   | 89.4   | 89.4   | 89.4   | 89.4   | 89.4   | 89.4   | 89.5   | 90.7   | 91.8   | 91.8   |
| Gas Pool W-O              | 81.2   | 81.2   | 81.2   | 81.2   | 81.2   | 81.2   | 81.2   | 81.2   | 81.2   | 81.2   | 81.0   | 81.0   | 82.6   | 82.6   |
| Distillate to Petchem     | 180    | 180    | 191    | 191    | 202    | 202    | 214    | 214    | 227    | 227    | 241    | 241    | 255    | 255    |
| RTI to Petchem            | 140    | 140    | 147    | 147    | 155    | 155    | 163    | 163    | 171    | 171    | 181    | 181    | 191    | 191    |
| LPG to Petchem            | 83     | 83     | 87     | 87     | 92     | 92     | 96     | 96     | 102    | 102    | 107    | 107    | 113    | 113    |
| TOTAL PETCHEM             | 403    | 403    | 425    | 425    | 449    | 449    | 473    | 473    | 500    | 500    | 529    | 529    | 559    | 559    |

TABLE V-13  
REFINERY MATERIAL BALANCES NO/CD  
CASE 2: ACTUAL REFINERY - 93/95 RON/MEN LEAD FREE OCTANE

TABLE V-13

REFINED DATA

|                           | 1974   | 1975   | 1976   | 1977   | 1978   | 1979   | 1980   |
|---------------------------|--------|--------|--------|--------|--------|--------|--------|
|                           | A      | E      | A      | E      | A      | E      | A      |
| Total Crude Intake        | 13,533 | 14,490 | 15,362 | 16,351 | 17,136 | 18,245 | 19,559 |
| Δ Crude A vs. B/B vs. C   | (1)    | (1)    | 15     | 14     | 17,136 | 18,245 | 19,559 |
| Δ Crude %                 | (0.01) | (0.01) | 0.04   | 0.09   | 0.39   | 0.47   | 0.60   |
| Total Intake              | 14,513 | 15,402 | 16,197 | 17,051 | 17,806 | 18,824 | 19,941 |
| Δ Intake A vs. B/B vs. C  | (1)    | (1)    | 15     | 14     | 17,806 | 18,824 | 19,941 |
| Δ Intake %                | (0.01) | (0.01) | 0.09   | 0.09   | 0.38   | 0.47   | 0.63   |
| Gasoline Production       | 6,988  | 7,265  | 7,576  | 7,875  | 8,176  | 8,499  | 8,862  |
| % Crude Production        | 51.64  | 50.14  | 49.32  | 48.30  | 47.71  | 46.58  | 45.31  |
| % Total Intake            | 48.15  | 47.17  | 46.77  | 46.18  | 45.92  | 44.85  | 44.44  |
| Distillates - % Crude     | 22.66  | 22.43  | 22.42  | 22.35  | 22.61  | 22.50  | 22.27  |
| Low Sulfur Fuel - % Crude | 8.28   | 9.94   | 10.67  | 11.57  | 11.60  | 12.59  | 13.57  |
| Dist. + Ldly % Crude      | 30.94  | 32.37  | 33.11  | 33.92  | 34.21  | 35.09  | 35.84  |
| LPG - % Crude             | 2.89   | 2.64   | 2.62   | 2.59   | 2.60   | 2.58   | 2.54   |
| Total Product Outturn     | 14,059 | 14,912 | 15,677 | 16,499 | 17,209 | 18,155 | 19,176 |
| Δ Outturn A vs. B/B vs. C | (1)    | (1)    | 15     | 14     | 17,209 | 18,155 | 19,176 |
| Δ Outturn %               | (0.01) | (0.01) | 0.10   | 0.09   | 0.20   | 0.20   | 0.20   |
| Intake - Outturn          | 454    | 490    | 520    | 532    | 595    | 669    | 765    |
| Δ A vs. B/B vs. C         | (1)    | (1)    | 15     | 14     | 595    | 669    | 765    |
| Δ % Crude                 | (0.01) | (0.01) | 0.10   | 0.09   | 0.20   | 0.20   | 0.20   |
| Total Refinery Fuel       | 1,050  | 1,118  | 1,187  | 1,261  | 1,329  | 1,407  | 1,499  |
| % Crude Intake            | 7.76   | 7.72   | 7.73   | 7.73   | 7.76   | 7.71   | 7.66   |
| Purchased Power - F.O.E.  | 100    | 106    | 113    | 119    | 127    | 132    | 140    |
| Car Crack Coke - F.O.E.   | 77     | 82     | 86     | 90     | 94     | 97     | 100    |
| Energy Consumed           | 1,227  | 1,306  | 1,366  | 1,470  | 1,550  | 1,636  | 1,739  |
| % Crude Intake            | 9.07   | 9.01   | 9.02   | 9.02   | 9.05   | 8.97   | 8.89   |

TABLE V-14  
REFINERY MATERIAL BALANCES MB/CD  
CASE 3: ACTUAL REFINERY - 7% GROWTH GASOLINE DEMAND

REDUCED DATA

|                           | 1974   |        |   | 1975   |        |        | 1976   |        |        | 1977   |        |        | 1978   |        |        | 1979   |        |        | 1980   |        |        |
|---------------------------|--------|--------|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                           | A      | B      | C | A      | B      | C      | A      | B      | C      | A      | B      | C      | A      | B      | C      | A      | B      | C      | A      | B      | C      |
| Total Crude Intake        | 13,532 | 13,532 |   | 14,696 | 14,696 | 14,697 | 15,847 | 15,847 | 15,866 | 17,064 | 17,076 | 17,134 | 18,347 | 18,393 | 18,284 | 19,709 | 19,668 | 19,795 | 21,247 | 21,348 | 21,382 |
| Δ Crude A vs. B/B vs. C   |        |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Δ Crude %                 |        |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Total Intake              | 14,512 | 14,512 |   | 15,608 | 15,608 | 15,609 | 16,082 | 16,082 | 16,701 | 17,812 | 17,824 | 17,882 | 19,015 | 19,061 | 18,932 | 20,288 | 20,247 | 20,374 | 21,629 | 21,730 | 21,954 |
| Δ Intake A vs. B/B vs. C  |        |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Δ Intake %                |        |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Gasoline Production       | 6,988  | 6,988  |   | 7,456  | 7,456  | 7,456  | 8,024  | 8,024  | 8,024  | 8,575  | 8,575  | 8,575  | 9,154  | 9,154  | 9,154  | 9,783  | 9,783  | 9,783  | 10,504 | 10,504 | 10,504 |
| Δ Crude Intake            | 51.64  | 51.64  |   | 50.73  | 50.73  | 50.73  | 50.63  | 50.57  | 50.57  | 50.25  | 50.22  | 50.05  | 49.89  | 49.77  | 50.07  | 49.64  | 49.74  | 49.42  | 49.44  | 49.20  | 49.13  |
| % Total Intake            | 48.15  | 48.15  |   | 47.77  | 47.77  | 47.77  | 48.10  | 48.05  | 48.14  | 48.11  | 47.95  | 47.95  | 48.14  | 48.02  | 48.30  | 48.22  | 48.32  | 48.02  | 48.56  | 48.34  | 47.85  |
| Distillates - % Crude     | 22.66  | 22.66  |   | 22.11  | 22.11  | 22.11  | 21.76  | 21.73  | 21.35  | 21.34  | 21.27  | 21.12  | 21.06  | 21.19  | 21.19  | 20.83  | 20.87  | 20.74  | 20.50  | 20.40  | 20.37  |
| Low Sulfur Fuel - % Crude | 8.28   | 8.28   |   | 9.81   | 9.81   | 9.80   | 10.34  | 10.33  | 11.06  | 11.05  | 11.01  | 11.77  | 11.74  | 10.87  | 10.87  | 12.16  | 11.68  | 11.60  | 12.96  | 12.44  | 12.42  |
| Dist. + LSGF - % Crude    | 30.94  | 30.94  |   | 31.92  | 31.92  | 31.91  | 32.10  | 32.06  | 32.41  | 32.39  | 32.28  | 32.89  | 32.80  | 32.06  | 32.06  | 32.97  | 32.55  | 32.34  | 33.46  | 32.84  | 32.79  |
| LPG - % Crude             | 2.64   | 2.69   |   | 2.60   | 2.60   | 2.60   | 2.54   | 2.53   | 2.48   | 2.48   | 2.46   | 2.53   | 2.61   | 2.63   | 2.63   | 2.40   | 2.57   | 2.56   | 2.34   | 2.51   | 2.50   |
| Total Product Outturn     | 14,059 | 14,059 |   | 15,103 | 15,103 | 15,103 | 16,125 | 16,125 | 16,125 | 17,099 | 17,099 | 17,132 | 18,377 | 18,393 | 18,221 | 19,537 | 19,475 | 19,475 | 20,818 | 20,856 | 20,856 |
| Δ Outturn A vs. B/B vs. C |        |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Δ Outturn %               |        |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Intake - Outturn          | 453    | 453    |   | 505    | 505    | 506    | 557    | 557    | 576    | 713    | 725    | 750    | 638    | 668    | 731    | 751    | 772    | 899    | 811    | 874    | 1,098  |
| Δ A vs. B/B vs. C         |        |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Δ % Crude                 |        |        |   |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| Total Refinery Fuel       | 1,050  | 1,050  |   | 1,141  | 1,141  | 1,141  | 1,242  | 1,242  | 1,242  | 1,344  | 1,344  | 1,365  | 1,474  | 1,471  | 1,488  | 1,582  | 1,606  | 1,649  | 1,717  | 1,761  | 1,795  |
| % Crude Intake            | 7.76   | 7.76   |   | 7.76   | 7.76   | 7.76   | 7.84   | 7.83   | 7.83   | 7.68   | 7.67   | 7.97   | 8.03   | 8.00   | 8.14   | 8.03   | 8.16   | 8.33   | 8.08   | 8.25   | 8.39   |
| Purchased Power - F.O.E.  | 100    | 100    |   | 108    | 108    | 108    | 117    | 117    | 117    | 127    | 127    | 127    | 144    | 141    | 140    | 149    | 152    | 151    | 160    | 165    | 162    |
| Cat Crk. Coke - F.O.E.    | 77     | 77     |   | 83     | 83     | 85     | 95     | 95     | 99     | 104    | 107    | 105    | 99     | 109    | 114    | 120    | 117    | 109    | 133    | 127    | 120    |
| Energy Consumed           | 1,227  | 1,227  |   | 1,334  | 1,334  | 1,334  | 1,454  | 1,454  | 1,454  | 1,575  | 1,578  | 1,597  | 1,717  | 1,721  | 1,742  | 1,851  | 1,873  | 1,909  | 2,010  | 2,053  | 2,077  |
| % Crude Intake            | 9.07   | 9.07   |   | 9.08   | 9.08   | 9.08   | 9.18   | 9.18   | 9.19   | 9.23   | 9.24   | 9.32   | 9.36   | 9.36   | 9.53   | 9.39   | 9.32   | 9.64   | 9.46   | 9.62   | 9.71   |



TABLE V-15                      REFINERY MATERIAL BALANCES MB/CD  
CASE 4: ACTUAL REFINERY - REDUCED LEAD FREE DEMANDS

REDUCED DATA

|                              | 1976      |           |           | 1979      |           |           |
|------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                              | <u>A</u>  | <u>B</u>  | <u>C</u>  | <u>A</u>  | <u>B</u>  | <u>C</u>  |
| Total Crude Intake           | 15,362    | 15,362    | 15,385    | 18,245    | 18,255    | 18,406    |
| Δ Crude A vs. B/B vs. C      |           | -         | 23        |           | 10        | 151       |
| Δ Crude %                    |           | -         | 0.15      |           | 0.05      | 0.83      |
| Total Intake                 | 16,197    | 16,197    | 16,220    | 18,824    | 18,834    | 18,985    |
| Δ Intake A vs. B/B vs. C     |           | -         | 23        |           | 10        | 151       |
| Δ Intake %                   |           | -         | 0.14      |           | 0.05      | 0.80      |
| <br>Gasoline Production      | <br>7,576 | <br>7,576 | <br>7,576 | <br>8,499 | <br>8,499 | <br>8,499 |
| % Crude Intake               | 49.32     | 49.32     | 49.24     | 46.58     | 46.56     | 46.18     |
| % Total Intake               | 46.77     | 46.77     | 46.71     | 45.15     | 45.13     | 44.77     |
| <br>Distillates - % Crude    | <br>22.44 | <br>22.44 | <br>22.41 | <br>22.50 | <br>22.49 | <br>22.30 |
| Low Sulfur Fuel - % Crude    | 10.67     | 10.67     | 10.65     | 12.59     | 12.58     | 12.48     |
| Dist. + LoSF - % Crude       | 33.11     | 33.11     | 33.06     | 35.09     | 35.07     | 34.78     |
| <br>LPG - % Crude            | <br>2.62  | <br>2.62  | <br>2.61  | <br>2.58  | <br>2.57  | <br>2.75  |
| Total Product Outturn        | 15,677    | 15,677    | 15,677    | 18,155    | 18,155    | 18,191    |
| Δ Outturn A vs. B/B vs. C    |           | -         | -         |           | -         | 36        |
| Δ Outturn %                  |           | -         | -         |           | -         | 0.20      |
| <br>Intake - Outturn         | <br>520   | <br>520   | <br>543   | <br>669   | <br>679   | <br>794   |
| Δ A vs. B/B vs. C            |           | -         | 23        |           | 10        | 115       |
| Δ % Crude                    |           | -         | 0.15      |           | 0.05      | 0.63      |
| <br>Total Refinery Fuel      | <br>1,187 | <br>1,187 | <br>1,189 | <br>1,407 | <br>1,409 | <br>1,456 |
| % Crude Intake               | 7.73      | 7.73      | 7.73      | 7.71      | 7.72      | 7.91      |
| <br>Purchased Power - F.O.E. | <br>113   | <br>113   | <br>111   | <br>132   | <br>133   | <br>132   |
| Cat Crk Coke - F.O.E.        | 86        | 86        | 92        | 97        | 100       | 98        |
| <br>Energy Consumed          | <br>1,386 | <br>1,386 | <br>1,392 | <br>1,636 | <br>1,642 | <br>1,686 |
| % Crude Intake               | 9.02      | 9.02      | 9.05      | 8.97      | 8.99      | 9.16      |

TABLE V-16 REFINERY MATERIAL BALANCES MB/CD  
CASE 5: ACTUAL REFINERY - RESTRICTED REFINING CAPACITY

REDUCED DATA

|                           | 1974   |        | 1975   |        |        | 1976   |        |        |
|---------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
|                           | A      | B      | A      | B      | C      | A      | B      | C      |
| Total Crude Intake        | 13,517 | 13,517 | 14,496 | 14,502 | 14,502 | 15,396 | 15,404 | 15,404 |
| ΔCrude A vs. B/B vs. C    |        | -      |        | 6      | -      |        | 8      | -      |
| ΔCrude %                  |        | -      |        | 0.04   | -      |        | 0.05   | -      |
| Total Intake              | 14,721 | 14,721 | 15,628 | 15,634 | 15,634 | 16,447 | 16,455 | 16,455 |
| ΔIntake A vs. B/B vs. C   |        | -      |        | 6      | -      |        | 8      | -      |
| ΔIntake %                 |        | -      |        | 0.04   | -      |        | 0.05   | -      |
| Gasoline Production       | 6,988  | 6,988  | 7,265  | 7,265  | 7,265  | 7,576  | 7,576  | 7,576  |
| % Crude Intake            | 51.70  | 51.70  | 50.12  | 50.10  | 50.10  | 49.21  | 49.18  | 49.18  |
| % Total Intake            | 47.47  | 47.47  | 46.49  | 50.10  | 50.10  | 46.06  | 46.04  | 46.04  |
| Distillates - % Crude     | 22.69  | 22.69  | 22.42  | 22.41  | 22.41  | 22.40  | 22.38  | 22.38  |
| Low Sulfur Fuel - % Crude | 8.29   | 8.29   | 9.94   | 9.94   | 9.94   | 10.65  | 10.64  | 10.64  |
| Dist. + LoSF - % Crude    | 30.98  | 30.98  | 32.36  | 32.35  | 32.35  | 33.05  | 33.02  | 33.02  |
| LPG - % Crude             | 2.69   | 2.69   | 2.64   | 2.63   | 2.63   | 2.61   | 2.61   | 2.61   |
| Total Product Outturn     | 14,059 | 14,059 | 14,912 | 14,912 | 14,912 | 15,677 | 15,677 | 15,677 |
| ΔOutturn A vs. B/B vs. C  |        | -      |        | -      | -      |        | -      | -      |
| ΔOutturn %                |        | -      |        | -      | -      |        | -      | -      |
| Intake - Outturn          | 662    | 662    | 716    | 722    | 722    | 780    | 778    | 778    |
| ΔA vs. B/B vs. C          |        | -      |        | 6      | -      |        | (2)    | -      |
| Δ% Crude                  |        | -      |        | 0.04   | -      |        | (0.01) | -      |
| Total Refinery Fuel       | 1,055  | 1,055  | 1,116  | 1,125  | 1,125  | 1,189  | 1,200  | 1,200  |
| % Crude Intake            | 7.80   | 7.80   | 7.70   | 7.76   | 7.76   | 7.72   | 7.79   | 7.79   |
| Purchased Power - F.O.E.  | 89     | 89     | 94     | 94     | 94     | 100    | 100    | 100    |
| Cat Crack Coke - F.O.E.   | 94     | 94     | 98     | 97     | 97     | 105    | 102    | 102    |
| Energy Consumed           | 1,238  | 1,238  | 1,308  | 1,316  | 1,316  | 1,394  | 1,402  | 1,402  |
| % Crude Intake            | 9.16   | 9.16   | 9.02   | 9.07   | 9.07   | 9.05   | 9.10   | 9.10   |
| Cat Crk Conv - %          | 75     | 75     | 78     | 77     | 77     | 79     | 79     | 79     |
| Reformer R-0              | 92     |        |        |        |        | 92     | 92     | 92     |
| Gas Pool R-0              | 90.5   |        |        |        |        | 90.6   | 90.5   | 90.5   |
| Gas Pool M-0              | 81.7   |        |        |        |        | 81.7   | 81.7   | 81.7   |

TABLE V-17  
REFINERY MATERIAL BALANCES MB/CD  
CASE 6: ACTUAL REFINERY - RESTRICTED CAPACITIES, FLEXIBILITY STUDIES

REDUCED DATA

|                           | SUMMER (9.5 RVP) |        |        |        | WINTER (12 RVP) |        |        |        |
|---------------------------|------------------|--------|--------|--------|-----------------|--------|--------|--------|
|                           | 1974             |        | 1975   |        | 1974            |        | 1975   |        |
|                           | A                | B      | A      | B      | A               | B      | A      | B      |
| Total Crude Intake        | 14,005           | 14,005 | 14,706 | 14,706 | 14,005          | 14,005 | 14,706 | 14,706 |
| Δ Crude A vs. B/B vs. C   |                  |        |        |        |                 |        |        |        |
| Δ Crude %                 |                  |        |        |        |                 |        |        |        |
| Total Intake              | 15,141           | 15,142 | 15,750 | 15,801 | 15,209          | 15,209 | 15,838 | 15,838 |
| Δ Intake A vs. B/B vs. C  |                  |        |        |        |                 |        |        |        |
| Δ Intake %                |                  |        |        |        |                 |        |        |        |
| Gasoline Production       | 7,079            | 7,077  | 7,420  | 7,381  | 7,671           | 7,679  | 7,535  | 7,536  |
| % Crude Intake            | 50.55            | 50.53  | 50.46  | 50.19  | 49.62           | 49.67  | 48.59  | 48.58  |
| % Total Intake            | 46.75            | 46.74  | 47.11  | 46.71  | 46.58           | 46.57  | 45.21  | 45.15  |
| Distillates - % Crude     | 23.04            | 23.06  | 22.13  | 22.56  | 22.61           | 22.21  | 22.66  | 22.73  |
| Low Sulfur Fuel - % Crude | 8.92             | 8.92   | 9.31   | 9.49   | 10.30           | 10.12  | 12.64  | 12.67  |
| Dist. + LoSF - % Crude    | 31.96            | 31.98  | 31.44  | 32.05  | 32.91           | 32.33  | 35.30  | 35.40  |
| LPG - % Crude             | 2.60             | 2.60   | 2.60   | 2.60   | 2.60            | 2.60   | 2.80   | 2.80   |
| Total Product Outturn     | 14,439           | 14,440 | 15,000 | 15,051 | 15,774          | 15,692 | 15,847 | 15,846 |
| Δ Outturn A vs. B/B vs. C |                  |        |        |        |                 |        |        |        |
| Δ Outturn %               |                  |        |        |        |                 |        |        |        |
| Intake - Outturn          | 702              | 702    | 750    | 750    | 694             | 797    | 598    | 593    |
| Δ A vs. B/B vs. C         |                  |        |        |        |                 |        |        |        |
| Δ % Crude                 |                  |        |        |        |                 |        |        |        |
| Total Refinery Fuel       | 1,092            | 1,092  | 1,157  | 1,149  | 1,212           | 1,212  | 926    | 923    |
| % Crude Intake            | 7.80             | 7.80   | 7.87   | 7.81   | 8.40            | 7.84   | 6.61   | 6.59   |
| Purchased Power - F.O.E.  | 90               | 92     | 95     | 95     | 100             | 100    | 81     | 81     |
| Cat Crk Coke - F.O.E.     | 105              | 105    | 109    | 110    | 116             | 116    | 57     | 57     |
| Energy Consumed           | 1,287            | 1,289  | 1,361  | 1,354  | 1,428           | 1,428  | 1,064  | 1,061  |
| % Crude Intake            | 9.19             | 9.20   | 9.25   | 9.21   | 9.24            | 9.24   | 7.60   | 7.58   |
| Cat Crk Conv - %V         | 76               | 76     | 80     | 77     | 77              | 77     | 65     | 65     |
| Reformer R-0              | 92               | 92     | 92     | 92     | 92              | 92     | 98     | 98     |
| Gasol Pool R-0            | 90.4             | 90.4   | 90.0   | 90.1   | 90.0            | 90.1   | 91.0   | 91.0   |
| Gasol Pool N-0            | 81.3             | 81.3   | 81.0   | 81.0   | 81.0            | 81.0   | 82.6   | 82.7   |

TABLE V-18

 REFINERY MATERIAL BALANCES MB/CD  
 CASE 7: ACTUAL REFINERY - REDUCED PREMIUM DEMAND
REDUCED DATA

|                           | 1979     |          |          |
|---------------------------|----------|----------|----------|
|                           | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude Intake        | 18,245   | 18,271   | 18,346   |
| ΔCrude A vs. B/B vs. C    |          | 26       | 75       |
| ΔCrude %                  |          | 0.14     | 0.41     |
| Total Intake              | 18,824   | 18,850   | 18,925   |
| ΔIntake A vs. B/B vs. C   |          | 26       | 75       |
| ΔIntake %                 |          | 0.14     | 0.40     |
| Gasoline Production       | 8,500    | 8,500    | 8,500    |
| % Crude Intake            | 46.59    | 46.52    | 46.33    |
| % Total Intake            | 45.16    | 45.09    | 44.91    |
| Distillates - % Crude     | 22.50    | 22.47    | 22.38    |
| Low Sulfur Fuel - % Crude | 12.59    | 12.57    | 12.52    |
| Dist. + LoSF - % Crude    | 35.09    | 35.04    | 34.90    |
| LPG - % Crude             | 2.58     | 2.57     | 2.76     |
| Total Product Outturn     | 18,156   | 18,156   | 18,192   |
| ΔOutturn A vs. B/B vs. C  |          | -        | 36       |
| ΔOutturn %                |          | -        | 0.20     |
| Intake - Outturn          | 668      | 694      | 733      |
| ΔA vs. B/B vs. C          |          | 26       | 39       |
| Δ% Crude                  |          | 0.14     | 0.21     |
| Total Refinery Fuel       | 1,407    | 1,423    | 1,439    |
| % Crude Intake            | 7.71     | 7.79     | 7.84     |
| Purchased Power - F.O.E.  | 132      | 135      | 135      |
| Cat Crack Coke - F.O.E.   | 97       | 95       | 99       |
| Energy Consumed           | 1,636    | 1,653    | 1,673    |
| % Crude Intake            | 8.97     | 9.05     | 9.12     |
| Cat Crk Conv - %V         | 65       | 68       | 72       |

REFINERY MATERIAL BALANCES NO/CD  
CASE 1: COMPLEX REFINERY - UNRESTRICTED CASES

TABLE V-19

REDUCED DATA

|                           | 1974   | 1975   | 1976   | 1977   | 1978   | 1979   | 1980   |
|---------------------------|--------|--------|--------|--------|--------|--------|--------|
| Total Crude Intake        | 13,493 | 14,460 | 15,375 | 16,303 | 17,134 | 18,248 | 19,565 |
| Δ Crude A vs. B/B vs. C   | -      | -      | (14)   | (3)    | 31     | 73     | 48     |
| Δ Crude %                 | -      | -      | (0.09) | (0.19) | 0.18   | 0.40   | 0.25   |
| Total Intake              | 14,646 | 15,530 | 16,312 | 17,215 | 18,001 | 19,017 | 20,136 |
| Δ Intake A vs. B/B vs. C  | 5      | -      | 15     | (39)   | (2)    | 17     | 48     |
| Δ Intake %                | 0.03   | -      | 0.09   | (0.34) | (0.01) | 0.09   | 0.24   |
| Gasoline Production       | 6,988  | 7,265  | 7,576  | 7,875  | 8,176  | 8,499  | 8,842  |
| % Crude Intake            | 51.79  | 50.24  | 47.27  | 46.30  | 47.72  | 46.57  | 45.30  |
| % Total Intake            | 47.71  | 46.78  | 46.44  | 45.74  | 45.42  | 44.69  | 44.01  |
| Distillates - % Crude     | 22.73  | 22.48  | 22.43  | 22.35  | 22.61  | 22.80  | 22.26  |
| Low Sulfur Fuel - % Crude | 8.30   | 9.97   | 10.46  | 11.57  | 11.60  | 12.59  | 13.51  |
| Dist. + LoSF - % Crude    | 31.03  | 32.45  | 33.09  | 33.92  | 34.21  | 35.09  | 35.83  |
| LPG - % Crude             | 2.70   | 2.64   | 2.61   | 2.59   | 2.60   | 2.58   | 2.54   |
| Total Product Outturn     | 14,059 | 14,912 | 15,677 | 16,499 | 17,209 | 18,155 | 19,176 |
| Δ Outturn A vs. B/B vs. C | -      | -      | -      | (27)   | -      | -      | 8      |
| Δ Outturn %               | -      | -      | -      | (0.18) | -      | -      | 0.04   |
| Intake - Outturn          | 587    | 548    | 635    | 716    | 792    | 862    | 960    |
| Δ A vs. B/B vs. C         | 5      | -      | 15     | (32)   | (2)    | (17)   | 48     |
| Δ % Crude                 | 0.04   | -      | 0.10   | (0.20) | (0.01) | (0.09) | 0.25   |
| Total Refinery Fuel       | 1,029  | 1,096  | 1,166  | 1,227  | 1,289  | 1,367  | 1,461  |
| % Crude Intake            | 7.63   | 7.58   | 7.58   | 7.33   | 7.52   | 7.49   | 7.47   |
| Purchased Power - P.O.E.  | 92     | 98     | 104    | 108    | 113    | 119    | 125    |
| Cat Crack Coke - P.O.E.   | 90     | 92     | 94     | 97     | 108    | 109    | 112    |
| Energy Consumed           | 1,211  | 1,286  | 1,362  | 1,435  | 1,510  | 1,590  | 1,698  |
| % Crude Intake            | 8.98   | 8.89   | 8.85   | 8.80   | 8.81   | 8.74   | 8.68   |
| Cat Crk Conv - %          | 65     | 65     | 65     | 65     | 65     | 65     | 65     |
| Reformer R-O              | 92     | 91     | 91     | 94     | 95     | 95     | 98     |

V-21



TABLE V-20

## REFINERY MATERIAL BALANCES MB/CD

CASE 2: COMPLEX REFINERY - 93/85 RON/MON LEAD FREE OCTANE

REDUCED DATA

|                           | 1976     |          |          | 1979     |          |          |
|---------------------------|----------|----------|----------|----------|----------|----------|
|                           | <u>A</u> | <u>B</u> | <u>C</u> | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude Intake        | 15,378   | 15,417   | 15,455   | 18,248   | 18,376   | 18,341   |
| ΔCrude A vs. B/B vs. C    |          | 39       | 38       |          | 128      | (35)     |
| ΔCrude %                  |          | 0.25     | 0.25     |          | 0.70     | (0.19)   |
| Total Intake              | 16,311   | 16,301   | 16,291   | 19,019   | 19,011   | 19,118   |
| ΔIntake A vs. B/B vs. C   |          | (10)     | (10)     |          | (8)      | 107      |
| ΔIntake %                 |          | (0.06)   | (0.06)   |          | (0.04)   | 0.56     |
| Gasoline Production       | 7,576    | 7,576    | 7,576    | 8,499    | 8,499    | 8,499    |
| % Crude Intake            | 49.27    | 49.14    | 49.02    | 46.57    | 46.25    | 46.34    |
| % Total Intake            | 46.45    | 46.48    | 46.50    | 46.67    | 44.71    | 44.46    |
| Distillates - % Crude     | 22.42    | 22.36    | 22.31    | 22.50    | 22.34    | 22.38    |
| Low Sulfur Fuel - % Crude | 10.66    | 10.63    | 10.60    | 12.59    | 12.50    | 12.52    |
| Dist. + LoSF - % Crude    | 33.08    | 32.99    | 32.91    | 35.09    | 34.84    | 35.20    |
| LPG - % Crude             | 2.61     | 2.61     | 2.60     | 2.58     | 2.56     | 2.76     |
| Total Product Outturn     | 15,677   | 15,677   | 15,677   | 18,155   | 18,155   | 18,191   |
| ΔOutturn A vs. B/B vs. C  |          | -        | -        |          | -        | 36       |
| ΔOutturn %                |          | -        | -        |          | -        | 0.20     |
| Intake - Outturn          | 634      | 624      | 614      | 864      | 856      | 927      |
| ΔA vs. B/B vs. C          |          | (10)     | (10)     |          | (8)      | 71       |
| Δ% Crude                  |          | (0.06)   | (0.06)   |          | (0.04)   | 0.39     |
| Total Refinery Fuel       | 1,166    | 1,170    | 1,177    | 1,367    | 1,416    | 1,432    |
| % Crude Intake            | 7.58     | 7.59     | 7.62     | 7.49     | 7.71     | 7.81     |
| Purchased Power - F.O.E.  | 105      | 106      | 106      | 119      | 124      | 127      |
| Cat Crack Coke - F.O.E.   | 92       | 92       | 93       | 110      | 116      | 119      |
| Energy Consumed           | 1,363    | 1,368    | 1,376    | 1,596    | 1,656    | 1,678    |
| % Crude Intake            | 8.86     | 8.87     | 8.90     | 8.75     | 9.01     | 9.15     |

TABLE V-21                      REFINERY MATERIAL BALANCES MB/CD  
CASE 3: COMPLEX REFINERY - 7% GROWTH GASOLINE DEMAND

REDUCED DATA

|                           | 1976     |          |          | 1979     |          |          |
|---------------------------|----------|----------|----------|----------|----------|----------|
|                           | <u>A</u> | <u>B</u> | <u>C</u> | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude Intake        | 15,907   | 15,878   | 15,906   | 19,627   | 19,682   | 19,758   |
| ΔCrude A vs B/B vs. C     |          | (29)     | 28       |          | 55       | 76       |
| ΔCrude %                  |          | (0.18)   | 0.18     |          | 0.28     | 0.39     |
| Total Intake              | 16,742   | 16,771   | 16,780   | 20,404   | 20,448   | 20,535   |
| ΔIntake A vs. B/B vs. C   |          | 29       | 9        |          | 44       | 87       |
| ΔIntake %                 |          | 0.17     | 0.05     |          | 0.22     | 0.43     |
| Gasoline Production       | 8,024    | 8,024    | 8,024    | 9,783    | 9,783    | 9,783    |
| % Crude Intake            | 50.44    | 50.54    | 50.45    | 49.84    | 49.71    | 49.51    |
| % Total Intake            | 47.93    | 47.84    | 47.82    | 47.95    | 47.84    | 47.64    |
| Distillates - % Crude     | 21.68    | 21.72    | 21.68    | 20.92    | 20.86    | 20.78    |
| Low Sulfur Fuel - % Crude | 10.30    | 10.32    | 10.30    | 11.72    | 11.67    | 11.63    |
| Dist. + LoSF - % Crude    | 31.98    | 32.04    | 31.98    | 32.64    | 32.53    | 32.41    |
| LPG - % Crude             | 2.53     | 2.53     | 2.53     | 2.39     | 2.57     | 2.56     |
| Total Product Outturn     | 16,125   | 16,125   | 16,125   | 19,443   | 19,474   | 19,475   |
| ΔOutturn A vs. B/B vs. C  |          | -        | -        |          | 31       | 1        |
| ΔOutturn %                |          | -        | -        |          | 0.16     | 0.01     |
| Intake - Outturn          | 617      | 646      | 655      | 961      | 974      | 1,060    |
| ΔA vs. B/B vs. C          |          | 29       | 9        |          | 13       | 86       |
| Δ% Crude                  |          | 0.18     | 0.06     |          | 0.07     | 0.44     |
| Total Refinery Fuel       | 1,229    | 1,225    | 1,226    | 1,539    | 1,584    | 1,604    |
| % Crude Intake            | 7.73     | 7.72     | 7.71     | 7.84     | 8.05     | 8.12     |
| Purchased Power - F.O.E.  | 113      | 111      | 111      | 136      | 140      | 140      |
| Cat Crack Coke - F.O.E.   | 93       | 97       | 101      | 132      | 121      | 129      |
| Energy Consumed           | 1,435    | 1,433    | 1,438    | 1,807    | 1,845    | 1,873    |
| % Crude Intake            | 9.02     | 9.03     | 9.04     | 9.21     | 9.37     | 9.48     |

TABLE V-22

## REFINERY MATERIAL BALANCES MB/CD

CASE 4: COMPLEX REFINERY - REDUCED LEAD FREE DEMANDS

REDUCED DATA

|                           | 1976     |          |          | 1979     |          |          |
|---------------------------|----------|----------|----------|----------|----------|----------|
|                           | <u>A</u> | <u>B</u> | <u>C</u> | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude Intake        | 15,375   | 15,337   | 15,377   | 18,248   | 18,251   | 18,351   |
| Δ Crude A vs. B/B vs. C   |          | (38)     | 40       |          | 3        | 100      |
| Δ Crude %                 |          | (0.25)   | 0.26     |          | 0.02     | 0.55     |
| Total Intake              | 16,312   | 16,349   | 16,345   | 19,017   | 19,028   | 19,073   |
| Δ Intake A vs. B/B vs. C  |          | 37       | (4)      |          | 11       | 45       |
| Δ Intake %                |          | 0.23     | (0.02)   |          | 0.06     | 0.24     |
| Gasoline Production       | 7,576    | 7,576    | 7,576    | 8,499    | 8,499    | 8,499    |
| % Crude Intake            | 49.27    | 49.40    | 49.27    | 46.57    | 46.57    | 46.31    |
| % Total Intake            | 46.44    | 46.34    | 46.35    | 44.69    | 44.67    | 44.56    |
| Distillates - % Crude     | 22.43    | 22.48    | 22.42    | 22.50    | 22.49    | 22.37    |
| Low Sulfur Fuel - % Crude | 10.66    | 10.69    | 10.66    | 12.59    | 12.59    | 12.52    |
| Dist. + LoSF - % Crude    | 33.09    | 33.17    | 33.08    | 35.09    | 35.08    | 34.89    |
| LPG - % Crude             | 2.61     | 2.62     | 2.61     | 2.58     | 2.58     | 2.74     |
| Total Product Outturn     | 15,677   | 15,677   | 15,677   | 18,155   | 18,155   | 18,188   |
| Δ Outturn A vs. B/B vs. C |          | -        | -        |          | -        | 33       |
| Δ Outturn %               |          | -        | -        |          | -        | 0.18     |
| Intake - Outturn          | 635      | 672      | 668      | 862      | 873      | 885      |
| Δ A vs. B/B vs. C         |          | 37       | (4)      |          | 11       | 12       |
| Δ % Crude                 |          | 0.24     | (0.03)   |          | 0.06     | 0.07     |
| Total Refinery Fuel       | 1,166    | 1,158    | 1,164    | 1,367    | 1,371    | 1,412    |
| % Crude Intake            | 7.58     | 7.55     | 7.57     | 7.49     | 7.51     | 7.69     |
| Purchased Power - F.O.E.  | 105      | 102      | 103      | 119      | 119      | 127      |
| Cat Crack Coke - F.O.E.   | 92       | 97       | 99       | 109      | 111      | 118      |
| Energy Consumed           | 1,363    | 1,357    | 1,366    | 1,595    | 1,601    | 1,657    |
| % Crude Intake            | 8.87     | 8.85     | 8.88     | 8.74     | 8.77     | 9.03     |

TABLE V-23

ECONOMIC SUMMARY \$/MB/DAY  
CASE 1: ACTUAL REFINERY - UNRESTRICTED CASES

|                            | 1974   |       | 1975  |       | 1976   |        | 1977   |        | 1978   |        | 1979   |        | 1980   |        |
|----------------------------|--------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                            | R-A    | C-B   | R-A   | C-B   | R-A    | C-B    | R-A    | C-B    | R-A    | C-B    | R-A    | C-B    | R-A    | C-B    |
| Raw Materials Cost         |        |       |       |       |        |        |        |        |        |        |        |        |        |        |
| Δ Crude                    | -      | -     | -     | -     | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Isobutane                | -      | -     | -     | -     | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Normal Butane            | -      | -     | -     | -     | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Operating Cost           | (0.03) | -     | 0.01  | -     | (0.03) | (0.10) | (0.17) | (0.18) | (0.20) | (0.22) | (0.33) | (0.33) | (0.51) | (0.18) |
| Δ Capital Cost @ 20%       | -      | -     | -     | -     | -      | -      | (0.03) | 0.02   | 0.14   | 0.06   | 0.09   | (0.19) | 0.10   | (0.09) |
| By-Product Value           |        |       |       |       |        |        |        |        |        |        |        |        |        |        |
| Δ LPC                      | -      | -     | -     | -     | -      | -      | -      | (0.13) | -      | (0.23) | (0.05) | (0.23) | (0.30) | -      |
| Δ Low Sulfur Fuel          | -      | -     | -     | -     | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Total Cost                 | (0.03) | -     | 0.01  | -     | (0.03) | 0.02   | (0.06) | 0.09   | 0.08   | 0.14   | 0.12   | 0.34   | 0.33   | 0.28   |
| Gas Volume MB/D            | 7.0    | 7.3   | 7.3   | 7.3   | 7.6    | 7.6    | 7.9    | 7.9    | 8.2    | 8.2    | 8.5    | 8.5    | 8.9    | 8.9    |
| Penalty c/Bbl              | (0.4)  | -     | 0.1   | -     | (0.7)  | 0.3    | (0.6)  | 1.1    | 0.7    | 1.7    | 1.4    | 4.0    | 3.7    | 3.1    |
| (Billions of 1974 \$)      |        |       |       |       |        |        |        |        |        |        |        |        |        |        |
| Case A Total Plant Invest. | 19.14  | 20.39 | 20.39 | 20.39 | 21.69  | 21.69  | 23.06  | 23.06  | 24.28  | 24.28  | 25.62  | 25.62  | 27.00  | 27.00  |
| Δ Total Plant Investment   | 0      | 0     | 0     | 0     | 0      | 0      | (0.03) | 0.03   | 0.08   | 0.07   | 0.13   | (0.29) | 0.13   | (0.11) |
| Cumulative Δ Plant Invest. | 0      | 0     | 0     | 0     | 0      | 0      | (0.03) | 0.03   | 0.03   | 0.10   | 0.16   | (0.19) | 0.29   | (0.30) |

ECONOMIC SUMMARY 9/10/74

[illegible]



TABLE V-25  
ECONOMIC SUMMARY \$MM/DAY  
CASE 3: ACTUAL REFINERY - 7% GROWTH GASOLINE DEMAND

|                            | 1974   |       |        | 1975   |        |        | 1976   |        |        | 1977   |        |        | 1978   |        |        | 1979   |        |        | 1980   |        |     |
|----------------------------|--------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-----|
|                            | B-A    | B-A   | C-B    | B-A    | B-A    | C-B    | B-A    | B-A    | C-B    | B-A    | B-A    | C-B    | B-A    | B-A    | C-B    | B-A    | B-A    | C-B    | B-A    | B-A    | C-B |
| New Materials Cost         |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |
| Δ Crude                    | -      | -     | 0.01   | -      | -      | 0.16   | -      | -      | 0.52   | 0.11   | 0.52   | -      | 0.43   | (1.0)  | -      | (0.40) | 1.23   | -      | 1.02   | 0.34   | -   |
| Δ Isobutane                | -      | -     | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | 0.75   | -   |
| Δ Normal Butane            | -      | -     | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | 0.75   | -   |
| Δ Operating Cost           | (0.03) | 0.01  | (0.01) | (0.04) | (0.14) | (0.21) | (0.16) | (0.21) | 0.03   | (0.16) | (0.21) | (0.28) | (0.28) | (0.39) | (0.38) | (0.38) | (0.43) | (0.52) | (0.52) | (0.34) | -   |
| Δ Capital Cost @ 20%       | -      | -     | -      | -      | -      | -      | -      | -      | -      | -      | -      | (0.08) | (0.08) | (0.21) | 0.12   | (0.26) | -      | 0.22   | 0.22   | (0.33) | -   |
| By-Product Value           |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |
| Δ LPG                      | -      | -     | -      | -      | -      | -      | -      | -      | (0.23) | -      | (0.23) | (0.12) | (0.12) | -      | (0.23) | -      | -      | (0.30) | -      | -      | -   |
| Δ Low Sulfur Fuel          | -      | -     | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | 1.83   | 1.1    | -      | -      | -      | -      | -      | -   |
| Total Cost                 | (0.03) | 0.01  | -      | (0.04) | 0.02   | 0.13   | (0.03) | 0.13   | 0.13   | (0.03) | 0.13   | (0.01) | 0.23   | 0.23   | 0.21   | 0.56   | 0.42   | 1.17   | 0.42   | 1.17   | -   |
| Gaso Volume MM/D           | 7.0    | 7.5   | 7.5    | 8.0    | 8.0    | 8.6    | 8.6    | 8.6    | 8.6    | 8.6    | 8.6    | 9.2    | 9.2    | 9.2    | 9.8    | 9.8    | 10.5   | 10.5   | 10.5   | 10.5   | -   |
| Penalty c/Bbl              | (0.4)  | 0.1   | -      | (0.3)  | 0.3    | 1.5    | (0.6)  | 1.5    | 1.5    | (0.6)  | 1.5    | (0.1)  | 2.5    | 2.5    | 2.1    | 5.7    | 4.0    | 11.1   | 4.0    | 11.1   | -   |
| (Billions of 1974 \$)      |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |
| Case A Total Plant Invest. | 19.14  | 20.75 | 0      | 22.56  | 0      | 26.37  | 26.37  | 26.37  | 0.08   | 26.37  | 26.37  | 26.37  | 26.37  | 26.37  | 26.37  | 26.37  | 26.37  | 26.37  | 26.37  | 26.37  | -   |
| Δ Total Plant Investment   | 0      | 0     | 0      | 0      | 0      | 0      | 0      | 0      | 0.08   | 0      | 0.08   | (0.08) | (0.08) | (0.31) | 0.16   | (0.31) | 0.29   | (0.44) | 0.29   | (0.44) | -   |
| Cumulative Δ Plant Invest. | 0      | 0     | 0      | 0      | 0      | 0      | 0      | 0      | 0.08   | 0      | 0.08   | (0.08) | (0.08) | (0.23) | 0.08   | (0.56) | 0.37   | (1.00) | 0.37   | (1.00) | -   |

TABLE V-26

ECONOMIC SUMMARY \$MM/DAY  
CASE 4: ACTUAL REFINERY - REDUCED LEAD FREE DEMANDS

|                            | 1976         |              | 1979         |              |
|----------------------------|--------------|--------------|--------------|--------------|
|                            | <u>B - A</u> | <u>C - B</u> | <u>B - A</u> | <u>C - B</u> |
| Raw Materials Cost         |              |              |              |              |
| Δ Crude                    | -            | .20          | .10          | 1.46         |
| Δ Iso Butane               | -            | -            | -            | -            |
| Δ Norm Butane              | -            | -            | -            | -            |
| Δ Operating Cost           | .06          | (.18)        | (.18)        | (.43)        |
| Δ Capital Cost             | -            | .01          | .04          | (.07)        |
| By-Product Value           |              |              |              |              |
| Δ LPG                      | -            | -            | -            | (.27)        |
| Δ Low Sulfur Fuel Oil      | -            | -            | -            | -            |
| Total Cost                 | .06          | .03          | (.04)        | .69          |
| Gas Volume MMB/D           | 7.6          | 7.6          | 8.5          | 8.5          |
| Penalty ¢/BBL              | .8           | .4           | (.5)         | 8.1          |
| (Billions of 1974 Dollars) |              |              |              |              |
| Case A Total Plant Invest. | 21.63        |              | 25.62        |              |
| Δ Total Plant Invest.      | 0            | .02          | .06          | (.10)        |

TABLE V-27

## ECONOMIC SUMMARY \$MM/DAY

## CASE 5: ACTUAL REFINERY RESTRICTED REFINING CAPACITY

|                            | 1974         | 1975         |              | 1976         |              |
|----------------------------|--------------|--------------|--------------|--------------|--------------|
|                            | <u>B - A</u> | <u>B - A</u> | <u>C - B</u> | <u>B - A</u> | <u>C - B</u> |
| Raw Materials Cost         |              |              |              |              |              |
| Δ Crude                    | -            | .05          | -            | .07          | -            |
| Δ Iso Butane               | -            | -            | -            | -            | -            |
| Δ Norm Butane              | -            | -            | -            | -            | -            |
| Δ Operating Cost           | (.04)        | (.01)        | -            | -            | -            |
| Δ Capital Cost             | -            | (.03)        | -            | (.05)        | -            |
| By-Product Value           |              |              |              |              |              |
| Δ LPG                      | -            | -            | -            | -            | -            |
| Δ Low Sulfur Fuel Oil      | -            | -            | -            | -            | -            |
| Total Cost                 | (.04)        | .01          | -            | .02          | -            |
| Gas Volume MMB/D           | 7.0          | 7.3          | 7.3          | 7.6          | 7.6          |
| Penalty ¢/BBL              | (.6)         | .1           | -            | .3           | -            |
| (Billions of 1974 Dollars) |              |              |              |              |              |
| Case A Total Plant Invest. | 18.27        |              |              | 20.56        |              |
| Δ Total Plant Invest.      | 0            | (.04)        | 0            | (.08)        | 0            |

TABLE V-28

ECONOMIC SUMMARY \$MM/DAY  
CASE 7: ACTUAL REFINERY - REDUCED PREMIUM DEMAND

|                            | 1979         |              |
|----------------------------|--------------|--------------|
|                            | <u>B - A</u> | <u>C - B</u> |
| Raw Materials Cost         |              |              |
| Δ Crude                    | 0.25         | 0.72         |
| Δ Iso Butane               | -            | -            |
| Δ Norm Butane              | -            | -            |
| Δ Operating Cost           | .01          | (.25)        |
| Δ Capital Cost             | .10          | .05          |
| By-Product Value           |              |              |
| Δ LPG                      | -            | (.27)        |
| Δ Low Sulfur Fuel Oil      | -            | -            |
| Total Cost                 | .36          | .25          |
| Gas Volume MMB/D           | 8.5          | 8.5          |
| Penalty ¢/BBL              | 4.2          | 2.9          |
| Case A Total Plant Invest. | 25.62        |              |
| (Billions of 1974 Dollars) |              |              |
| Δ Total Plant Invest.      | .14          | .07          |

TABLE V-29

ECONOMIC SUMMARY \$MM/DAY  
CASE 1: COMPLEX REFINERY - UNRESTRICTED CASES

|                            | 1974   |     | 1975   |     | 1976   |        | 1977   |        | 1978   |        | 1979   |        | 1980   |        |
|----------------------------|--------|-----|--------|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                            | B-A    | C-B | B-A    | C-B | B-A    | C-B    | B-A    | C-B    | B-A    | C-B    | B-A    | C-B    | B-A    | C-B    |
| Raw Materials Cost         |        |     |        |     |        |        |        |        |        |        |        |        |        |        |
| Δ Crude                    | -      | -   | -      | -   | (0.12) | 0.25   | 0.18   | 0.86   | 0.29   | 0.97   | 0.70   | (0.22) | 0.48   | 0.09   |
| Δ Isobutane                | -      | -   | -      | -   | (0.28) | (0.16) | (0.15) | (0.30) | (0.18) | (0.36) | -      | -      | -      | -      |
| Δ Normal Butane            | -      | -   | -      | -   | 0.49   | (0.08) | (0.41) | -      | (0.06) | (0.64) | (0.43) | 0.49   | -      | -      |
| Δ Operating Cost           | (0.07) | -   | (0.01) | -   | (0.07) | (0.07) | (0.07) | (0.17) | (0.08) | (0.16) | (0.25) | (0.11) | (0.34) | (0.02) |
| Δ Capital Charge @ 20%     | (0.01) | -   | -      | -   | (0.04) | 0.06   | 0.13   | 0.17   | 0.08   | 0.32   | 0.15   | 0.31   | 0.29   | 0.23   |
| By-product Value           | -      | -   | -      | -   | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ LPG                      | -      | -   | -      | -   | -      | -      | 0.28   | (0.28) | -      | -      | -      | -      | -      | (0.06) |
| Δ Low Sulfur Fuel Oil      | -      | -   | -      | -   | -      | -      | (0.04) | 0.08   | 0.05   | 0.13   | 0.17   | 0.33   | 0.43   | 0.24   |
| Total Cost                 | (0.08) | -   | (0.01) | -   | (0.02) | 0      | (0.04) | 0.08   | 0.05   | 0.13   | 0.17   | 0.33   | 0.43   | 0.24   |
| Case Volume MBBL/D         | 7.0    | 7.3 | 7.3    | 7.3 | 7.6    | 7.6    | 7.9    | 7.9    | 8.2    | 8.2    | 8.5    | 8.5    | 8.9    | 8.9    |
| Penalty c/Bbl              | (1.1)  | -   | (0.1)  | -   | (0.3)  | -      | (0.5)  | 1.0    | 0.6    | 1.6    | 2.0    | 3.9    | 4.8    | 2.7    |
| (Billions of 1974 \$)      |        |     |        |     |        |        |        |        |        |        |        |        |        |        |
| Case A Total Plant Invest. | 20.64  |     | 21.89  |     | 23.30  |        | 24.44  |        | 25.75  |        | 27.31  |        | 28.93  |        |
| Δ Total Plant Investment   | (0.02) | 0   | 0      | 0   | (0.06) | 0.10   | 0.19   | 0.25   | 0.11   | 0.46   | 0.20   | 0.43   | 0.38   | 0.30   |
| Cumulative Δ Plant Invest. | (0.02) | 0   | (0.02) | 0   | (0.08) | 0.10   | 0.11   | 0.35   | 0.22   | 0.81   | 0.42   | 1.24   | 0.80   | 1.54   |



TABLE V-30

## ECONOMIC SUMMARY \$MM/DAY

CASE 2: COMPLEX REFINERY - 93/85 RON/MON LEAD FREE OCTANE

|                            | 1976         |              | 1979         |              |
|----------------------------|--------------|--------------|--------------|--------------|
|                            | <u>B - A</u> | <u>B - C</u> | <u>B - A</u> | <u>B - C</u> |
| Raw Materials Cost         |              |              |              |              |
| Δ Crude                    | .33          | .38          | 1.24         | (.34)        |
| Δ Iso Butane               | (.29)        | (.33)        | (.33)        | .33          |
| Δ Norm Butane              | (.04)        | .01          | (.71)        | .75          |
| Δ Operating Cost           | .02          | (.06)        | .03          | (.16)        |
| Δ Capital Charge @ 20%     | .08          | .08          | .54          | .20          |
| By-Product Values          |              |              |              |              |
| Δ LPG                      | -            | -            | -            | (.27)        |
| Δ Low Sulfur Fuel Oil      | -            | -            | -            | -            |
| Total Cost                 | .10          | .08          | .77          | .51          |
| Gas Volume MMB/D           | 7.6          | 7.6          | 8.5          | 8.5          |
| Penalty ¢/BBL              | 1.3          | 1.1          | 9.1          | 6.0          |
| Case A Total Plant Invest. | 22.89        |              | 27.29        |              |
| Δ Total Plant Invest.      | .55          | .14          | .75          | .26          |
| (Billions of 1974 Dollars) |              |              |              |              |

TABLE V-31

ECONOMIC SUMMARY \$MM/DAY  
CASE 3: COMPLEX REFINERY 7% GROWTH GASOLINE DEMAND

|                            | 1976         |              | 1979         |              |
|----------------------------|--------------|--------------|--------------|--------------|
|                            | <u>B - A</u> | <u>C - B</u> | <u>B - A</u> | <u>C - B</u> |
| Raw Materials Cost         |              |              |              |              |
| Δ Crude                    | (.25)        | .24          | .53          | .73          |
| Δ Iso Butane               | .38          | (.28)        | (.08)        | .08          |
| Δ Norm Butane              | .01          | .16          | -            | -            |
| Δ Operating Cost           | (.10)        | (.13)        | (.27)        | (.26)        |
| Δ Capital Charge @ 20%     | (.08)        | .03          | .29          | .06          |
| By-Product Values          |              |              |              |              |
| Δ LPG                      | -            | -            | (.26)        | (.01)        |
| Δ Low Sulfur Fuel Oil      | -            | -            | .04          | -            |
| Total Cost                 | (.04)        | .02          | .25          | .60          |
| Gas Volume MMB/D           | 8.0          | 8.0          | 9.8          | 9.8          |
| Penalty ¢/BBL              | (.5)         | .2           | 10.2         | 6.1          |
| Case A Total Plant Inv.    | 24.64        |              | 30.54        |              |
| Δ Total Plant Invest.      | (.13)        | .04          | .39          | .08          |
| (Billions of 1974 Dollars) |              |              |              |              |

TABLE V-32

## ECONOMIC SUMMARY \$MM/DAY

CASE 4: COMPLEX REFINERY - REDUCED LEAD FREE DEMAND

|                            | 1976         |              | 1979         |              |
|----------------------------|--------------|--------------|--------------|--------------|
|                            | <u>B - A</u> | <u>C - B</u> | <u>B - A</u> | <u>C - B</u> |
| Raw Materials Cost         |              |              |              |              |
| Δ Crude                    | (.32)        | .34          | .03          | .97          |
| Δ Iso Butane               | .09          | -            | -            | (.42)        |
| Δ Norm Butane              | .42          | (.30)        | .06          | -            |
| Δ Operating Cost           | (.02)        | (.11)        | (.11)        | (.14)        |
| Δ Capital Charge @ 20%     | (.11)        | .09          | .01          | .65          |
| By-Product Values          |              |              |              |              |
| Δ LPG                      | -            | -            | -            | (.29)        |
| Δ Low Sulfur Fuel Oil      | -            | -            | -            | -            |
| Total Cost                 | .06          | .02          | (.01)        | .77          |
| Gas Volume MMB/D           | 7.6          | 7.6          | 8.5          | 8.5          |
| Penalty c/BBL              | .8           | .3           | (.1)         | 9.1          |
| Case A Total Plant Inv.    | 23.30        |              | 27.31        |              |
| Δ Total Plant Invest.      | (.17)        | .14          | .01          | .89          |
| (Billions of 1974 Dollars) |              |              |              |              |

TABLE V-33

ENERGY BALANCES MB/CD  
(6.3 MB/CD T.O.E.)

CASE 1: ACTUAL REFINERY - UNRESTRICTED CASES

|                                | 1974   |        | 1975   |        | 1976   |        | 1977   |        | 1978   |        | 1979   |        | 1980   |        |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                                | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      |
| Total Crude                    | 12,028 | 12,028 | 12,879 | 12,879 | 12,879 | 12,879 | 13,655 | 13,655 | 15,232 | 15,232 | 16,218 | 16,218 | 17,386 | 17,386 |
| Δ Crude                        | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Crude, % of A                | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Purch. Refinery Fuel           | 490    | 490    | 441    | 441    | 387    | 387    | 325    | 325    | 257    | 257    | 181    | 181    | -      | -      |
| Natural Gasoline               | 359    | 359    | 345    | 345    | 326    | 326    | 310    | 310    | 301    | 301    | 292    | 292    | 280    | 280    |
| Isobutane                      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Normal Butane                  | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Total Raw Material In          | 12,877 | 12,877 | 13,665 | 13,665 | 14,370 | 14,370 | 15,127 | 15,127 | 15,790 | 15,790 | 16,691 | 16,691 | 17,666 | 17,666 |
| Δ TREC                         | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ TREC, % of A                 | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Outputs                        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| LPG                            | 220    | 220    | 231    | 231    | 243    | 243    | 256    | 256    | 270    | 270    | 288    | 288    | 301    | 324    |
| Δ LPG                          | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ LPG, % of A                  | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Distillates                    | 2,836  | 2,836  | 3,005  | 3,005  | 3,188  | 3,188  | 3,369  | 3,369  | 3,582  | 3,582  | 3,795  | 3,795  | 4,027  | 4,027  |
| Low Sulfur Fuel                | 1,067  | 1,067  | 1,372  | 1,372  | 1,561  | 1,561  | 1,797  | 1,797  | 1,893  | 1,893  | 2,188  | 2,188  | 2,529  | 2,529  |
| Purch. Power (PP)              | 100    | 100    | 106    | 106    | 113    | 113    | 119    | 119    | 127    | 127    | 132    | 132    | 140    | 140    |
| Δ Purch. Power                 | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Purch. Power, % of A         | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Refinery Fuel Consumed         | 1,050  | 1,050  | 1,118  | 1,118  | 1,187  | 1,187  | 1,261  | 1,261  | 1,329  | 1,329  | 1,407  | 1,407  | 1,499  | 1,530  |
| Cat Crack Coke                 | 77     | 77     | 81     | 81     | 86     | 86     | 90     | 90     | 94     | 94     | 97     | 97     | 100    | 107    |
| Total Energy Consumed          | 1,227  | 1,227  | 1,305  | 1,305  | 1,386  | 1,386  | 1,470  | 1,470  | 1,550  | 1,550  | 1,636  | 1,636  | 1,739  | 1,764  |
| TRE, % of Crude                | 10.2   | 10.2   | 10.1   | 10.1   | 10.15  | 10.15  | 10.16  | 10.22  | 10.18  | 10.21  | 10.29  | 10.18  | 10.00  | 10.14  |
| Δ TREC                         | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ TREC, % of A                 | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Energy Input=ΔTREC+ΔPP-ΔLPG  | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Base Energy Input=TREC+PP      | 12,977 | 0      | 13,771 | 0      | 14,483 | 0      | 15,246 | 0      | 15,917 | 0      | 16,823 | 0      | 17,806 | 18,388 |
| Δ Base Energy Input, % of Base | 0      | 0      | 0      | 0      | 0      | 0      | 0.083  | 0.085  | 0.075  | 0.075  | 0.202  | 0.202  | 0.52   | 0.26   |

TABLE V-34

ENERGY BALANCES MB/CD  
(6.3 MM Btu P.O.E.)  
CASE 2: ACTUAL REFINERY - 93/85 NON/NOV LEAD FREE OCTANE

|                            | 1974   |        | 1975   |        | 1976   |        | 1977   |        | 1978   |        | 1979   |        | 1980   |        |
|----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                            | A      | E      | A      | E      | A      | E      | A      | E      | A      | E      | A      | E      | A      | E      |
| Total Crude                | 12,029 | 12,028 | 12,880 | 12,879 | 13,655 | 13,648 | 14,573 | 14,573 | 15,232 | 15,291 | 15,307 | 16,218 | 16,277 | 16,356 |
| Δ Crude                    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    |
| Δ Crude, % of A            | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Purch. Refinery Fuel       | 490    | 490    | 441    | 441    | 387    | 387    | 325    | 325    | 257    | 257    | 257    | 181    | 181    | 181    |
| Natural Gasoline           | 359    | 359    | 345    | 345    | 329    | 329    | 310    | 310    | 301    | 301    | 292    | 292    | 292    | 292    |
| Isobutane                  | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Normal Butane              | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Total Raw Material In      | 12,878 | 12,877 | 13,666 | 13,665 | 14,371 | 14,384 | 15,126 | 15,126 | 15,790 | 15,849 | 15,865 | 16,691 | 16,790 | 16,888 |
| Δ TREC                     | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    |
| Δ TREC, % of A             | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| OUTPUTS                    |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| LPG                        | 220    | 220    | 231    | 231    | 243    | 243    | 256    | 256    | 270    | 269    | 291    | 284    | 306    | 306    |
| Δ LPG                      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ LPG, % of A              | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Distillates                | 2,836  | 2,836  | 3,005  | 3,005  | 3,188  | 3,188  | 3,369  | 3,369  | 3,582  | 3,582  | 3,795  | 3,795  | 3,795  | 3,795  |
| Low Sulfur Fuel            | 1,067  | 1,067  | 1,372  | 1,372  | 1,561  | 1,561  | 1,787  | 1,787  | 1,993  | 1,893  | 1,893  | 2,188  | 2,188  | 2,188  |
| Purchased Power            | 100    | 100    | 106    | 106    | 113    | 113    | 119    | 119    | 127    | 125    | 125    | 132    | 132    | 129    |
| Δ PP                       | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ PP, % of A               | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Refinery Fuel Consumed     | 1,050  | 1,050  | 1,118  | 1,119  | 1,187  | 1,189  | 1,261  | 1,264  | 1,329  | 1,337  | 1,347  | 1,407  | 1,429  | 1,459  |
| Cat Crack Cuts             | 77     | 77     | 82     | 81     | 86     | 90     | 90     | 99     | 94     | 105    | 111    | 97     | 107    | 108    |
| Total Energy Consumed      | 1,227  | 1,227  | 1,306  | 1,305  | 1,386  | 1,392  | 1,470  | 1,482  | 1,550  | 1,567  | 1,583  | 1,636  | 1,668  | 1,696  |
| TREC, % Crude              | 9.07   | 9.07   | 9.01   | 9.02   | 9.02   | 9.05   | 9.02   | 9.06   | 9.05   | 9.11   | 9.19   | 8.97   | 9.11   | 9.22   |
| Δ TREC                     | -      | -      | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    | (1)    |
| Δ TREC, % of A             | -      | -      | (0.06) | (0.06) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) |
| Δ Energy Input-TREC+LPG    | 12,478 | (1)    | 13,772 | (1)    | 14,484 | (1)    | 15,245 | (1)    | 15,917 | (1)    | 16,423 | (1)    | 17,806 | (1)    |
| Base Energy Input-TREC+LPG | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Δ Energy Input, % of Base  | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |



TABLE V-35

ENERGY BALANCES MB/CD  
(6.3 MM Btu P.O.E.)

CASE 3: ACTUAL REFINERY - 7% GROWTH GASOLINE DEMAND

|                            | 1974   |        | 1975   |        | 1976   |        | 1977   |        | 1978   |        | 1979   |        | 1980   |        |
|----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                            | A      | E      | A      | E      | A      | E      | A      | E      | A      | E      | A      | E      | A      | E      |
| Total Crude                | 12,027 | 12,027 | 13,062 | 13,062 | 14,085 | 14,085 | 15,177 | 15,239 | 16,307 | 16,348 | 17,517 | 17,581 | 18,884 | 18,974 |
| Δ Crude                    | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Crude, % of A            | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Purch. Refinery Fuel       | 490    | 490    | 441    | 441    | 387    | 387    | 325    | 325    | 257    | 257    | 181    | 181    | -      | -      |
| Natural Gasoline           | 359    | 359    | 345    | 345    | 329    | 329    | 310    | 310    | 301    | 301    | 292    | 292    | 280    | 280    |
| Isobutane                  | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Normal Butane              | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Total Raw Material In      | 12,876 | 12,876 | 13,848 | 13,848 | 14,801 | 14,801 | 15,801 | 15,864 | 16,865 | 16,906 | 17,990 | 18,067 | 19,164 | 19,254 |
| Δ TREC                     | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ TREC, % of A             | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| OUTPUTS                    |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| LPG                        | 220    | 220    | 231    | 231    | 243    | 243    | 256    | 276    | 281    | 291    | 286    | 306    | 301    | 324    |
| Δ LPG                      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ LPG, % of A              | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Distillates                | 2,836  | 2,836  | 3,005  | 3,005  | 3,188  | 3,188  | 3,369  | 3,369  | 3,582  | 3,582  | 3,795  | 3,795  | 4,027  | 4,027  |
| Low Sulfur Fuel            | 1,067  | 1,067  | 1,372  | 1,372  | 1,561  | 1,561  | 1,797  | 1,797  | 2,057  | 2,057  | 2,278  | 2,187  | 2,529  | 2,529  |
| Purch. Power               | 100    | 100    | 108    | 108    | 117    | 117    | 127    | 127    | 144    | 141    | 149    | 152    | 160    | 165    |
| Δ PP                       | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ PP, % of A               | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Refinery Fuel Consumed     | 1,050  | 1,050  | 1,141  | 1,141  | 1,242  | 1,242  | 1,344  | 1,344  | 1,474  | 1,471  | 1,582  | 1,604  | 1,717  | 1,761  |
| Cat Crack Coke             | 77     | 77     | 85     | 85     | 95     | 95     | 104    | 107    | 99     | 109    | 120    | 117    | 133    | 127    |
| Total Energy Consumed      | 1,227  | 1,227  | 1,334  | 1,334  | 1,454  | 1,454  | 1,578  | 1,597  | 1,717  | 1,721  | 1,851  | 1,873  | 2,010  | 2,053  |
| TCC, % Crude               | 10.20  | 10.20  | 10.21  | 10.21  | 10.32  | 10.34  | 10.40  | 10.49  | 10.53  | 10.53  | 10.57  | 10.71  | 10.64  | 10.82  |
| Δ TCC                      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ TCC, % of A              | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Energy Input-TREC-PP-LPG | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Base Energy Input-TREC-PP  | 12,976 | -      | 13,956 | -      | 14,918 | -      | 15,928 | -      | 17,009 | -      | 18,139 | -      | 19,324 | -      |
| Δ Energy Input, % of Base  | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |

TABLE V-36

ENERGY BALANCES MB/CD  
(6.3 MM Btu F.O.E.)

## CASE 4: ACTUAL REFINERY - REDUCED LEAD FREE DEMANDS

|                                                                 | 1976     |          |          | 1979     |          |          |
|-----------------------------------------------------------------|----------|----------|----------|----------|----------|----------|
|                                                                 | <u>A</u> | <u>B</u> | <u>C</u> | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude                                                     | 13,654   | 13,654   | 13,674   | 16,216   | 16,225   | 16,359   |
| $\Delta$ Crude                                                  |          | -        | 20       |          | 9        | 134      |
| $\Delta$ Crude, % of A                                          |          | -        | 0.15     |          | 0.06     | 0.83     |
| Purch. Refinery Fuel                                            | 387      | 387      | 387      | 181      | 181      | 181      |
| Natural Gasoline                                                | 329      | 329      | 329      | 292      | 292      | 292      |
| Isobutane                                                       | -        | -        | -        | -        | -        | -        |
| Normal Butane                                                   | -        | -        | -        | -        | -        | -        |
| Total Raw Material In                                           | 14,370   | 14,370   | 14,390   | 16,689   | 16,698   | 16,832   |
| $\Delta$ TRMI                                                   |          | -        | 20       |          | 9        | 134      |
| $\Delta$ TRMI, % of A                                           |          | -        | 0.14     |          | 0.05     | 0.80     |
| OUTPUTS                                                         |          |          |          |          |          |          |
| LPG                                                             | 243      | 243      | 243      | 284      | 284      | 306      |
| $\Delta$ LPG                                                    |          | -        | -        |          | -        | 22       |
| $\Delta$ LPG, % of A                                            |          | -        | -        |          | -        | 7.75     |
| Distillates                                                     | 3,188    | 3,188    | 3,188    | 3,795    | 3,795    | 3,795    |
| Low Sulfur Fuel                                                 | 1,561    | 1,561    | 1,561    | 2,188    | 2,188    | 2,188    |
| Purchased Power                                                 | 113      | 113      | 111      | 132      | 133      | 132      |
| $\Delta$ PP                                                     |          | -        | (2)      |          | 1        | (1)      |
| $\Delta$ PP, % of A                                             |          | -        | (1.77)   |          | 0.76     | (0.76)   |
| Refinery Fuel Used                                              | 1,187    | 1,187    | 1,189    | 1,407    | 1,409    | 1,456    |
| Cat Crack Coke                                                  | 86       | 86       | 92       | 97       | 100      | 98       |
| Total Energy Consumed                                           | 1,386    | 1,386    | 1,392    | 1,636    | 1,642    | 1,686    |
| TEC, % of Crude                                                 | 10.15    | 10.15    | 10.18    | 10.09    | 10.12    | 10.31    |
| $\Delta$ TEC                                                    |          | -        | 6        |          | 6        | 44       |
| $\Delta$ TEC, % of A                                            |          | -        | 0.43     |          | 0.37     | 2.69     |
| $\Delta$ Energy Input= $\Delta$ TRMI+ $\Delta$ PP- $\Delta$ LPG |          | -        | 18       |          | 10       | 111      |
| Base Energy Input= TRMI + PP                                    | 14,483   |          |          | 16,821   |          |          |
| $\Delta$ Energy Input, % of Base                                |          | -        | 0.12     |          | 0.06     | 0.66     |

TABLE V-37

ENERGY BALANCES MB/CD  
(6.3 MM Btu F.O.E.)

## CASE 5: ACTUAL REFINERY - RESTRICTED REFINING CAPACITY

|                               | 1974     |          | 1975     |          |          | 1976     |          |          |
|-------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|
|                               | <u>A</u> | <u>B</u> | <u>A</u> | <u>B</u> | <u>C</u> | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude                   | 12,015   | 12,015   | 12,885   | 12,891   | 12,891   | 13,685   | 13,692   | 13,692   |
| ΔCrude                        |          | -        |          | 6        | -        |          | 7        | -        |
| ΔCrude, % of A                |          | -        |          | 0.05     | -        |          | 0.05     | -        |
| Purch. Refinery Fuel          | 490      | 490      | 441      | 441      | 441      | 387      | 387      | 387      |
| Natural Gasoline              | 359      | 359      | 345      | 345      | 345      | 329      | 329      | 329      |
| Isobutane                     | 74       | 74       | 73       | 73       | 73       | 71       | 71       | 71       |
| Normal Butane                 | 77       | 77       | 52       | 52       | 52       | 74       | 74       | 74       |
| Total Raw Material In         | 13,015   | 13,015   | 13,796   | 13,802   | 13,802   | 14,546   | 14,553   | 14,553   |
| ΔTRMI                         |          | -        |          | 6        | -        |          | 7        | -        |
| ΔTRMI, % of A                 |          | -        |          | 0.04     | -        |          | 0.05     | -        |
| OUTPUTS                       |          |          |          |          |          |          |          |          |
| LPG                           | 220      | 220      | 231      | 231      | 231      | 243      | 243      | 243      |
| ΔLPG                          |          | -        |          | -        | -        |          | -        | -        |
| ΔLPG, % of A                  |          | -        |          | -        | -        |          | -        | -        |
| Distillates                   | 2,836    | 2,836    | 3,005    | 3,005    | 3,005    | 3,188    | 3,188    | 3,188    |
| Low Sulfur Fuel               | 1,067    | 1,067    | 1,372    | 1,372    | 1,372    | 1,561    | 1,561    | 1,561    |
| Purchased Power               | 89       | 89       | 94       | 94       | 94       | 100      | 100      | 100      |
| ΔPP                           |          | -        |          | -        | -        |          | -        | -        |
| ΔPP, % of A                   |          | -        |          | -        | -        |          | -        | -        |
| Refinery Fuel Used            | 1,055    | 1,055    | 1,116    | 1,125    | 1,125    | 1,189    | 1,200    | 1,200    |
| Cat Crack Coke                | 94       | 94       | 98       | 97       | 97       | 105      | 102      | 102      |
| Total Energy Consumed         | 1,238    | 1,238    | 1,308    | 1,316    | 1,316    | 1,394    | 1,402    | 1,402    |
| TEC, % of Crude               | 10.30    | 10.30    | 10.15    | 10.21    | 10.21    | 10.19    | 10.24    | 10.24    |
| ΔTEC                          |          | -        |          | 8        | -        |          | 8        | -        |
| ΔTEC, % of A                  |          | -        |          | 0.61     | -        |          | 0.57     | -        |
| Δ Energy Input=ΔTRMI+ΔPP-ΔLPG |          | -        |          | 6        | -        |          | 7        | -        |
| Base Energy Input=TRMI+PP     | 13,104   |          | 13,890   |          |          | 14,646   |          |          |
| ΔEnergy Input, % of Base      |          | -        |          | 0.04     | -        |          | 0.05     | -        |

TABLE V-38

ENERGY BALANCES MB/CD  
(6.3 MM Btu F.O.E.)

CASE 6: ACTUAL REFINERY - RESTRICTED CAPACITIES, FLEXIBILITY STUDIES

|                         | SUMMER (9.5 RVPL) |        |        |        |        | WINTER (12 RVPL) |        |        |        |        |
|-------------------------|-------------------|--------|--------|--------|--------|------------------|--------|--------|--------|--------|
|                         | 1974              |        | 1975   |        | 1976   |                  | 1974   |        | 1975   |        |
|                         | A                 | B      | A      | B      | A      | B                | A      | B      | A      | B      |
| Total Crude             | 12,449            | 12,449 | 13,072 | 13,072 | 13,742 | 13,742           | 12,449 | 12,449 | 13,072 | 13,072 |
| Δ Crude, % of A         | -                 | -      | -      | -      | -      | -                | -      | -      | -      | -      |
| Purchased Refinery Fuel | 490               | 490    | 441    | 441    | 387    | 387              | 490    | 490    | 441    | 441    |
| Natural Gasoline        | 359               | 359    | 345    | 345    | 329    | 329              | 359    | 359    | 345    | 345    |
| Isobutane               | 74                | 74     | 37     | 73     | 71     | 71               | 74     | 74     | 73     | 73     |
| Normal Butane           | 30                | 31     | 52     | 50     | 45     | 59               | 77     | 77     | 76     | 76     |
| Total Raw Material In   | 13,402            | 13,403 | 13,967 | 13,981 | 14,574 | 14,588           | 13,449 | 13,449 | 14,007 | 14,007 |
| Δ TRM                   | 1                 | 1      | 34     | (1)    | 14     | (67)             | -      | -      | -      | -      |
| Δ TRM, % of A           | 0.01              | 0.01   | 0.24   | (0.01) | 0.10   | (0.46)           | -      | -      | -      | -      |
| OUTPUTS                 |                   |        |        |        |        |                  |        |        |        |        |
| LPG                     | 220               | 220    | 231    | 231    | 243    | 243              | 237    | 237    | 249    | 249    |
| Δ LPG                   | -                 | -      | -      | -      | -      | -                | -      | -      | -      | -      |
| Δ LPG, % of A           | -                 | -      | -      | -      | -      | -                | -      | -      | -      | -      |
| Distillates             | 2,984             | 2,986  | 3,010  | 3,068  | 3,175  | 3,062            | 4,229  | 4,238  | 4,158  | 4,158  |
| Low Sulfur Fuel         | 1,190             | 1,190  | 1,304  | 1,330  | 1,517  | 1,437            | 1,686  | 1,690  | 1,801  | 1,801  |
| Purchased Power         | 90                | 92     | 95     | 95     | 100    | 102              | 81     | 81     | 87     | 87     |
| Δ PP                    | 2                 | 2      | -      | -      | -      | 2                | -      | -      | -      | -      |
| Δ PP, % of A            | 2.22              | 2.22   | -      | -      | -      | 2.00             | -      | -      | -      | -      |
| Refinery Fuel Used      | 1,092             | 1,092  | 1,157  | 1,149  | 1,212  | 1,234            | 926    | 973    | 982    | 984    |
| Cat Crack Coke          | 105               | 105    | 109    | 110    | 116    | 114              | 57     | 57     | 59     | 59     |
| Total Energy Consumed   | 1,287             | 1,289  | 1,361  | 1,357  | 1,428  | 1,450            | 1,064  | 1,061  | 1,128  | 1,130  |
| TEC, % of Crude         | 10.34             | 10.35  | 10.41  | 10.38  | 10.39  | 10.55            | 8.55   | 8.52   | 8.63   | 8.64   |
| Δ TEC                   | 2                 | 2      | (4)    | (3)    | 22     | (3)              | -      | -      | 2      | -      |
| Δ TEC, % of A           | 0.16              | 0.16   | (0.29) | (0.22) | 0.15   | (0.28)           | -      | -      | 0.18   | -      |

TABLE V-39

ENERGY BALANCES MB/CD  
(6.3 MM Btu F.O.E.)

## CASE 7: ACTUAL REFINERY - REDUCED PREMIUM DEMAND

|                               | 1979     |          |          |
|-------------------------------|----------|----------|----------|
|                               | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude                   | 16,218   | 16,241   | 16,308   |
| ΔCrude                        |          | 23       | 67       |
| ΔCrude, % of A                |          | 0.14     | 0.41     |
| Purch. Refinery Fuel          | 181      | 181      | 181      |
| Natural Gasoline              | 292      | 292      | 292      |
| Isobutane                     | -        | -        | -        |
| Normal Butane                 | -        | -        | -        |
| Total Raw Material In         | 16,691   | 16,714   | 16,781   |
| ΔTRMI                         |          | 23       | 67       |
| ΔTRMI, % of A                 |          | 0.14     | 0.40     |
| OUTPUTS                       |          |          |          |
| LPG                           | 284      | 284      | 306      |
| ΔLPG                          |          | -        | 22       |
| ΔLPG, % of A                  |          | -        | 7.75     |
| Distillates                   | 3,795    | 3,795    | 3,795    |
| Low Sulfur Fuel               | 2,188    | 2,188    | 2,188    |
| Purchased Power               | 132      | 135      | 135      |
| ΔPP                           |          | 3        | -        |
| ΔPP, % of A                   |          | 2.27     | -        |
| Refinery Fuel Used            | 1,407    | 1,423    | 1,439    |
| Cat Crack Coke                | 97       | 95       | 99       |
| Total Energy Consumed         | 1,636    | 1,653    | 1,673    |
| TEC, % of Crude               | 10.09    | 10.18    | 10.26    |
| ΔTEC                          |          | 17       | 20       |
| ΔTEC, % of A                  |          | 1.04     | 1.22     |
| Δ Energy Input=ΔTRMI+ΔPP-ΔLPG |          | 26       | 45       |
| Base Energy Input=TRMI+PP     | 16,823   |          |          |
| ΔEnergy Input, % of Base      |          | 0.15     | 0.27     |



TABLE V-40

ENERGY BALANCES MB/CD  
(6.3 MB Btu P.O.E.)

## CASE 1: COMPLEX REFINERY - UNRESTRICTED CASES

|                              | 1974   |        | 1975   |        | 1976   |        | 1977   |        | 1978   |        | 1979   |        | 1980   |        |
|------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                              | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      | A      | B      |
| Total Crude                  | 11,994 | 11,994 | 12,653 | 12,653 | 13,667 | 13,656 | 14,491 | 14,509 | 15,230 | 15,258 | 16,220 | 16,265 | 17,391 | 17,442 |
| Δ Crude                      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Crude, % of A              | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Purchased Refinery Fuel      | 490    | 490    | 441    | 441    | 387    | 387    | 325    | 325    | 257    | 257    | 181    | 181    | -      | -      |
| Natural Gasoline             | 359    | 359    | 365    | 365    | 329    | 329    | 310    | 310    | 301    | 301    | 292    | 292    | 280    | 280    |
| Isobutane                    | 74     | 74     | 73     | 73     | 62     | 62     | 70     | 70     | 88     | 88     | 65     | 65     | 63     | 63     |
| Normal Butane                | 42     | 42     | 32     | 32     | 5      | 5      | 40     | 40     | 66     | 66     | 62     | 62     | 65     | 65     |
| Total Raw Material In        | 12,959 | 12,962 | 13,744 | 13,744 | 14,450 | 14,456 | 15,236 | 15,240 | 15,922 | 15,927 | 16,820 | 16,867 | 17,798 | 17,850 |
| Δ TRM                        | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ TRM, % of A                | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| OUTPUTS                      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| LPG                          | 220    | 220    | 231    | 231    | 263    | 263    | 256    | 256    | 270    | 270    | 284    | 284    | 301    | 306    |
| Δ LPG                        | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ LPG, % of A                | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Distillates                  | 2,836  | 2,836  | 3,005  | 3,005  | 3,188  | 3,188  | 3,369  | 3,369  | 3,582  | 3,582  | 3,795  | 3,795  | 4,027  | 4,027  |
| Low Sulfur Fuel              | 1,067  | 1,067  | 1,372  | 1,372  | 1,561  | 1,561  | 1,797  | 1,797  | 1,893  | 1,893  | 2,188  | 2,188  | 2,529  | 2,529  |
| Purchased Power              | 92     | 92     | 98     | 98     | 104    | 104    | 108    | 110    | 113    | 113    | 119    | 119    | 125    | 125    |
| Δ PP                         | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ PP, % of A                 | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Refinery Fuel Used           | 1,029  | 1,029  | 1,096  | 1,096  | 1,166  | 1,166  | 1,227  | 1,235  | 1,289  | 1,296  | 1,367  | 1,360  | 1,461  | 1,509  |
| Cat Crack Coke               | 90     | 91     | 92     | 92     | 92     | 92     | 95     | 99     | 108    | 109    | 109    | 118    | 112    | 124    |
| Total Energy Consumed        | 1,211  | 1,212  | 1,286  | 1,286  | 1,362  | 1,362  | 1,435  | 1,442  | 1,510  | 1,518  | 1,595  | 1,617  | 1,698  | 1,735  |
| TEC, % Crude                 | 10.10  | 10.11  | 10.01  | 10.01  | 9.97   | 9.96   | 9.90   | 9.94   | 9.91   | 9.95   | 9.93   | 9.93   | 9.76   | 9.95   |
| Δ TEC                        | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ TEC, % of A                | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Energy Input-TRM-PP-LPG    | 13,051 | 13,051 | 13,842 | 13,842 | 14,554 | 14,554 | 15,364 | 15,364 | 16,035 | 16,035 | 16,939 | 16,939 | 17,924 | 18,026 |
| Base Energy Input-TRM-PP-LPG | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |
| Δ Energy Input, % of Base    | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      |

TABLE V-41

ENERGY BALANCES MB/CD  
(6.3 MM Btu F.O.E.)

CASE 2: COMPLEX REFINERY - 93/85 RON/MON LEAD FREE OCTANE

|                               | 1976   |        |        | 1979   |        |        |
|-------------------------------|--------|--------|--------|--------|--------|--------|
|                               | A      | B      | C      | A      | B      | C      |
| Total Crude                   | 13,699 | 13,704 | 13,738 | 16,220 | 16,334 | 16,303 |
| ΔCrude                        |        | 5      | 34     |        | 114    | (31)   |
| ΔCrude, % of A                |        | 0.04   | 0.25   |        | 0.70   | (0.19) |
| Purch. Refinery Fuel          | 387    | 387    | 387    | 181    | 181    | 181    |
| Natural Gasoline              | 329    | 329    | 329    | 292    | 292    | 292    |
| Isobutane                     | 61     | 32     | -      | 65     | 37     | 65     |
| Normal Butane                 | 4      | -      | 1      | 64     | -      | 68     |
| Total Raw Material In         | 14,480 | 14,452 | 14,455 | 16,822 | 16,844 | 16,909 |
| ΔTRMI                         |        | (28)   | 3      |        | 22     | 65     |
| ΔTRMI, % of A                 |        | (0.19) | 0.02   |        | 0.13   | 0.39   |
| OUTPUTS                       |        |        |        |        |        |        |
| LPG                           | 243    | 243    | 243    | 284    | 284    | 306    |
| ΔLPG                          |        | -      | -      |        | -      | 22     |
| ΔLPG, % of A                  |        | -      | -      |        | -      | 7.75   |
| Distillates                   | 3,188  | 3,188  | 3,188  | 3,795  | 3,795  | 3,795  |
| Low Sulfur Fuel               | 1,561  | 1,561  | 1,561  | 2,188  | 2,188  | 2,188  |
| Purchased Power               | 105    | 106    | 106    | 119    | 124    | 127    |
| ΔPP                           |        | 1      | -      |        | 5      | 3      |
| ΔPP, % of A                   |        | 0.95   | -      |        | 4.20   | 2.52   |
| Refinery Fuel Used            | 1,166  | 1,170  | 1,177  | 1,367  | 1,416  | 1,432  |
| Cat Crack Coke                | 92     | 92     | 93     | 110    | 116    | 119    |
| Total Energy Consumed         | 1,363  | 1,368  | 1,376  | 1,596  | 1,656  | 1,678  |
| TEC, % of Crude               | 9.95   | 9.98   | 10.02  | 9.84   | 10.14  | 10.29  |
| ΔTEC                          |        | 5      | 8      |        | 60     | 22     |
| ΔTEC, % of A                  |        | 0.37   | 0.59   |        | 3.76   | 1.38   |
| Δ Energy Input=ΔTRMI+ΔPP-ΔLPG |        | (27)   | 3      |        | 27     | 46     |
| Base Energy Input=TRMI+PP     | 14,585 |        |        | 16,941 |        |        |
| ΔEnergy Input, % of Base      |        | (0.19) | 0.02   |        | 0.16   | 0.27   |

TABLE V-42

ENERGY BALANCES MB/CD  
(6.3 MM Btu F.O.E.)

## CASE 3: COMPLEX REFINERY - 7% GROWTH GASOLINE DEMAND

|                               | 1976     |          |          | 1979     |          |          |
|-------------------------------|----------|----------|----------|----------|----------|----------|
|                               | <u>A</u> | <u>B</u> | <u>C</u> | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude                   | 14,139   | 14,114   | 14,139   | 17,446   | 17,495   | 17,562   |
| ΔCrude                        |          | (25)     | 25       |          | 49       | 67       |
| ΔCrude, % of A                |          | (0.18)   | 0.18     |          | 0.28     | 0.38     |
| Purch. Refinery Fuel          | 387      | 387      | 387      | 181      | 181      | 181      |
| Natural Gasoline              | 329      | 329      | 329      | 292      | 292      | 292      |
| Isobutane                     | -        | 37       | 9        | 65       | 58       | 65       |
| Normal                        | -        | 1        | 17       | 68       | 68       | 68       |
| Total Raw Material In         | 14,855   | 14,868   | 14,881   | 18,052   | 18,094   | 18,168   |
| ΔTRMI                         |          | 13       | 13       |          | 42       | 74       |
| ΔTRMI, % of A                 |          | 0.09     | 0.09     |          | 0.23     | 0.41     |
| OUTPUTS                       |          |          |          |          |          |          |
| LPG                           | 243      | 243      | 243      | 284      | 306      | 306      |
| ΔLPG                          |          | -        | -        |          | 22       | -        |
| ΔLPG, % of A                  |          | -        | -        |          | 7.75     | -        |
| Distillates                   | 3,188    | 3,188    | 3,188    | 3,795    | 3,795    | 3,795    |
| Low Sulfur Fuel               | 1,561    | 1,561    | 1,561    | 2,191    | 2,188    | 2,188    |
| Purchased Power               | 113      | 111      | 111      | 136      | 140      | 140      |
| ΔPP                           |          | (2)      | -        |          | 4        | -        |
| ΔPP, % of A                   |          | (1.77)   | -        |          | 2.94     | -        |
| Refinery Fuel Used            | 1,229    | 1,225    | 1,226    | 1,539    | 1,584    | 1,604    |
| Cat Crack Coke                | 93       | 97       | 101      | 132      | 121      | 129      |
| Total Energy Consumed         | 1,435    | 1,433    | 1,438    | 1,807    | 1,845    | 1,873    |
| TEC, % of Crude               | 10.15    | 10.15    | 10.17    | 10.36    | 10.55    | 10.67    |
| ΔTEC                          |          | (2)      | 5        |          | 38       | 28       |
| ΔTEC, % of A                  |          | (0.14)   | 0.35     |          | 2.10     | 1.55     |
| Δ Energy Input=ΔTRMI+ΔPP-ΔLPG |          | 11       | 13       |          | 24       | 74       |
| Base Energy Input= TRMI+PP    | 14,968   |          |          | 18,188   |          |          |
| ΔEnergy Input, % of Base      |          | 0.07     | 0.09     |          | 0.13     | 0.41     |

TABLE V-43

ENERGY BALANCES MB/CD  
(6.3 MM Btu F.O.E.)

## CASE 4: COMPLEX REFINERY - REDUCED LEAD FREE DEMAND

|                               | 1976     |          |          | 1979     |          |          |
|-------------------------------|----------|----------|----------|----------|----------|----------|
|                               | <u>A</u> | <u>B</u> | <u>C</u> | <u>A</u> | <u>B</u> | <u>C</u> |
| Total Crude                   | 13,667   | 13,633   | 13,668   | 16,220   | 16,223   | 16,312   |
| ΔCrude                        |          | (34)     | 35       |          | 3        | (11)     |
| ΔCrude, % of A                |          | (0.25)   | 0.26     |          | 0.02     | (0.07)   |
| Purch. Refinery Fuel          | 387      | 387      | 387      | 181      | 181      | 181      |
| Natural Gasoline              | 329      | 329      | 329      | 292      | 292      | 292      |
| Isobutane                     | 62       | 71       | 71       | 65       | 65       | 29       |
| Normal Butane                 | 5        | 47       | 17       | 62       | 68       | 68       |
| Total Raw Material In         | 14,450   | 14,467   | 14,472   | 16,820   | 16,829   | 16,882   |
| ΔTRMI                         |          | 17       | 5        |          | 9        | 53       |
| ΔTRMI, % of A                 |          | 0.12     | 0.03     |          | 0.05     | 0.32     |
| OUTPUTS                       |          |          |          |          |          |          |
| LPG                           | 243      | 243      | 243      | 284      | 284      | 304      |
| ΔLPG                          |          | -        | -        |          | -        | 20       |
| ΔLPG, % of A                  |          | -        | -        |          | -        | 7.04     |
| Distillates                   | 3,188    | 3,188    | 3,188    | 3,795    | 3,795    | 3,795    |
| Low Sulfur Fuel               | 1,561    | 1,561    | 1,561    | 2,188    | 2,188    | 2,188    |
| Purchased Power               | 105      | 102      | 103      | 119      | 119      | 127      |
| ΔPP                           |          | (3)      | 1        |          | -        | 8        |
| ΔPP, % of A                   |          | (2.86)   | 0.95     |          | -        | 6.72     |
| Refinery Fuel Used            | 1,166    | 1,158    | 1,164    | 1,367    | 1,371    | 1,412    |
| Cat Crack Coke                | 92       | 97       | 99       | 109      | 111      | 118      |
| Total Energy Consumed         | 1,363    | 1,357    | 1,366    | 1,595    | 1,601    | 1,657    |
| TEC, % of Crude               | 9.97     | 9.95     | 9.99     | 9.83     | 9.87     | 10.16    |
| ΔTEC                          |          | (6)      | 9        |          | 6        | 56       |
| ΔTEC, % of A                  |          | (0.44)   | 0.66     |          | 0.38     | 3.51     |
| Δ Energy Input=ΔTRMI+ΔPP-ΔLPG |          | 14       | 6        |          | 9        | 41       |
| Base Energy Input= TRMI+PP    | 14,555   |          |          | 16,939   |          |          |
| ΔEnergy Input, % of Base      |          | 0.10     | 0.04     |          | 0.05     | 0.24     |





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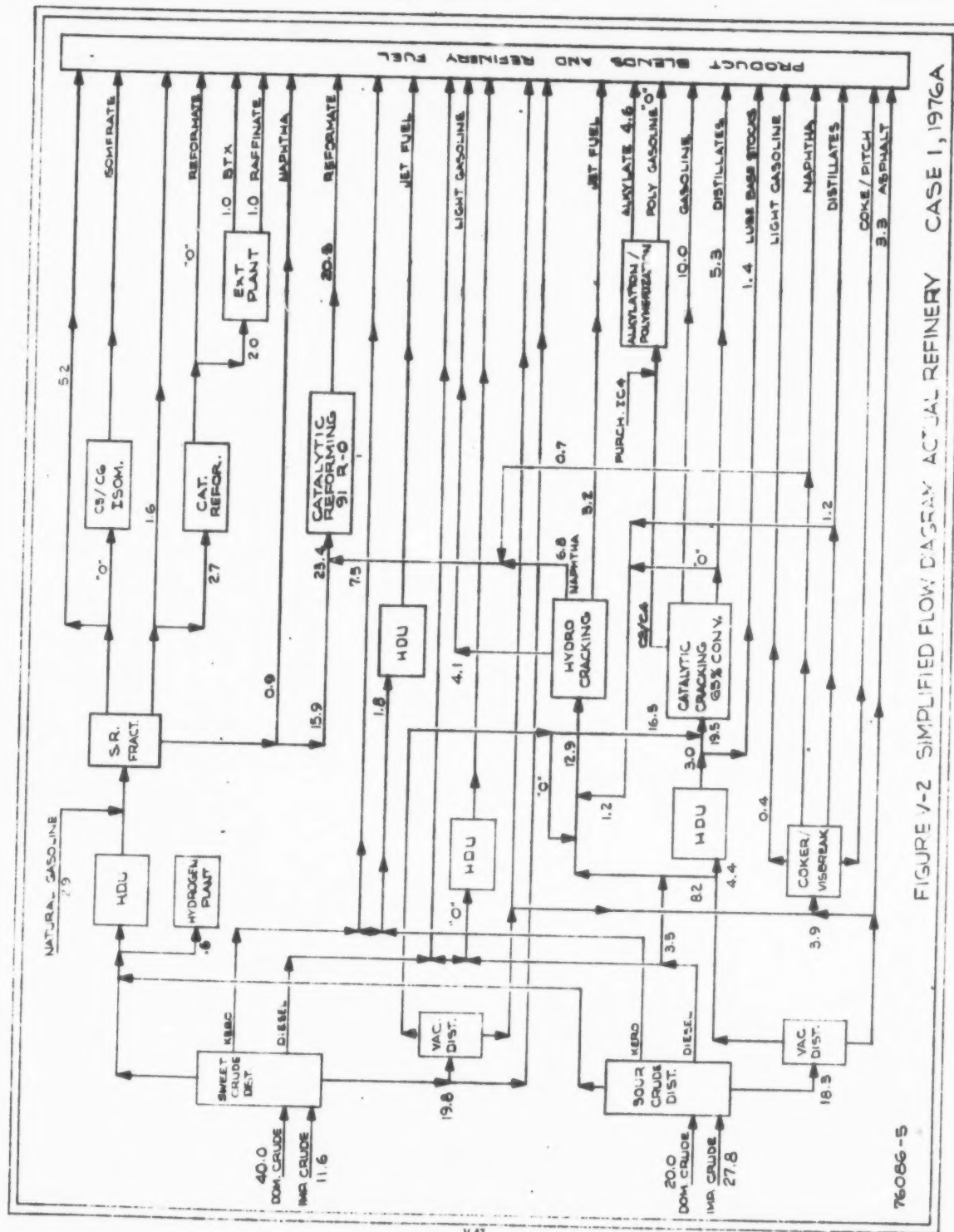


FIGURE V-2 SIMPLIFIED FLOW DIAGRAM ACTUAL REFINERY CASE 1, 1976A

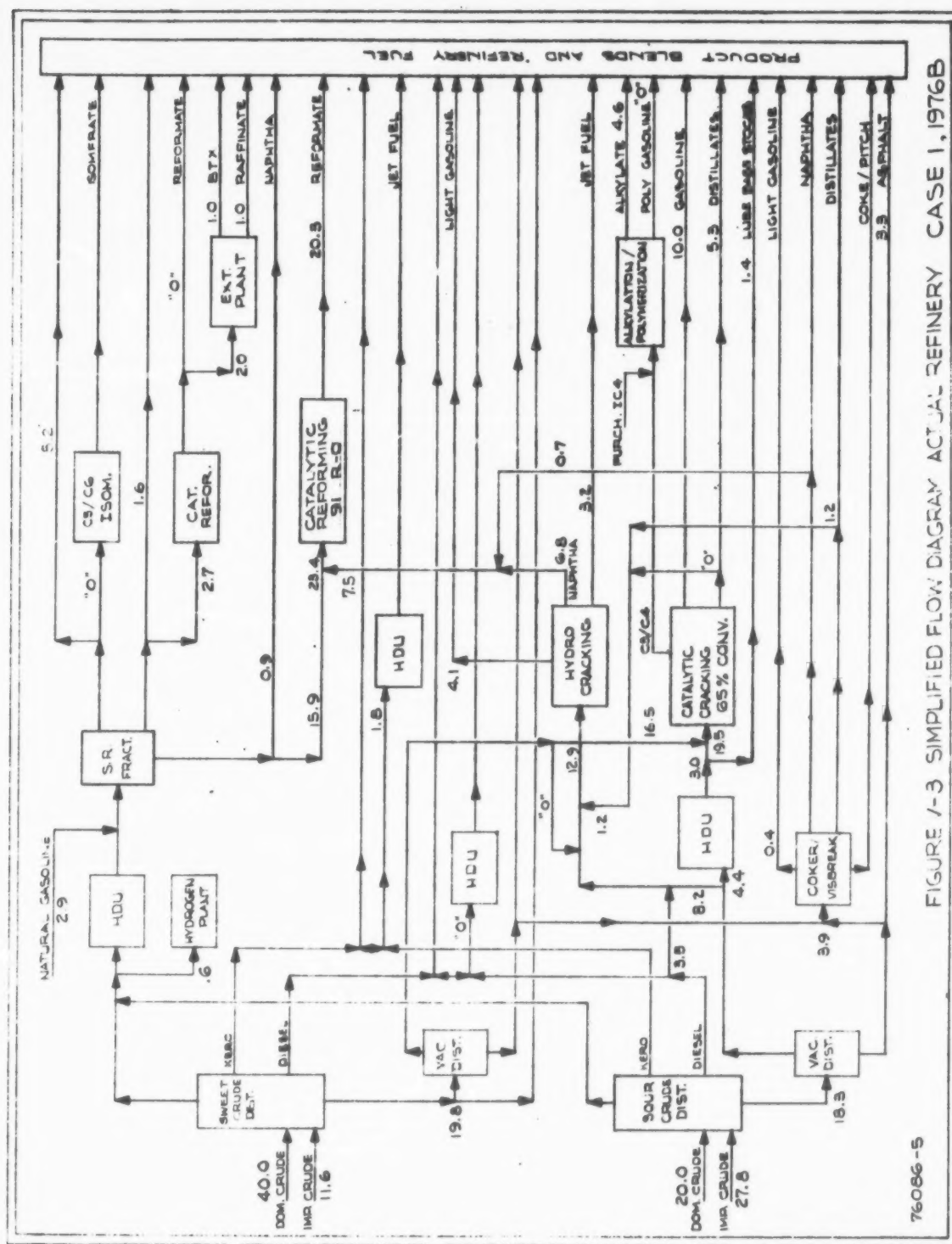
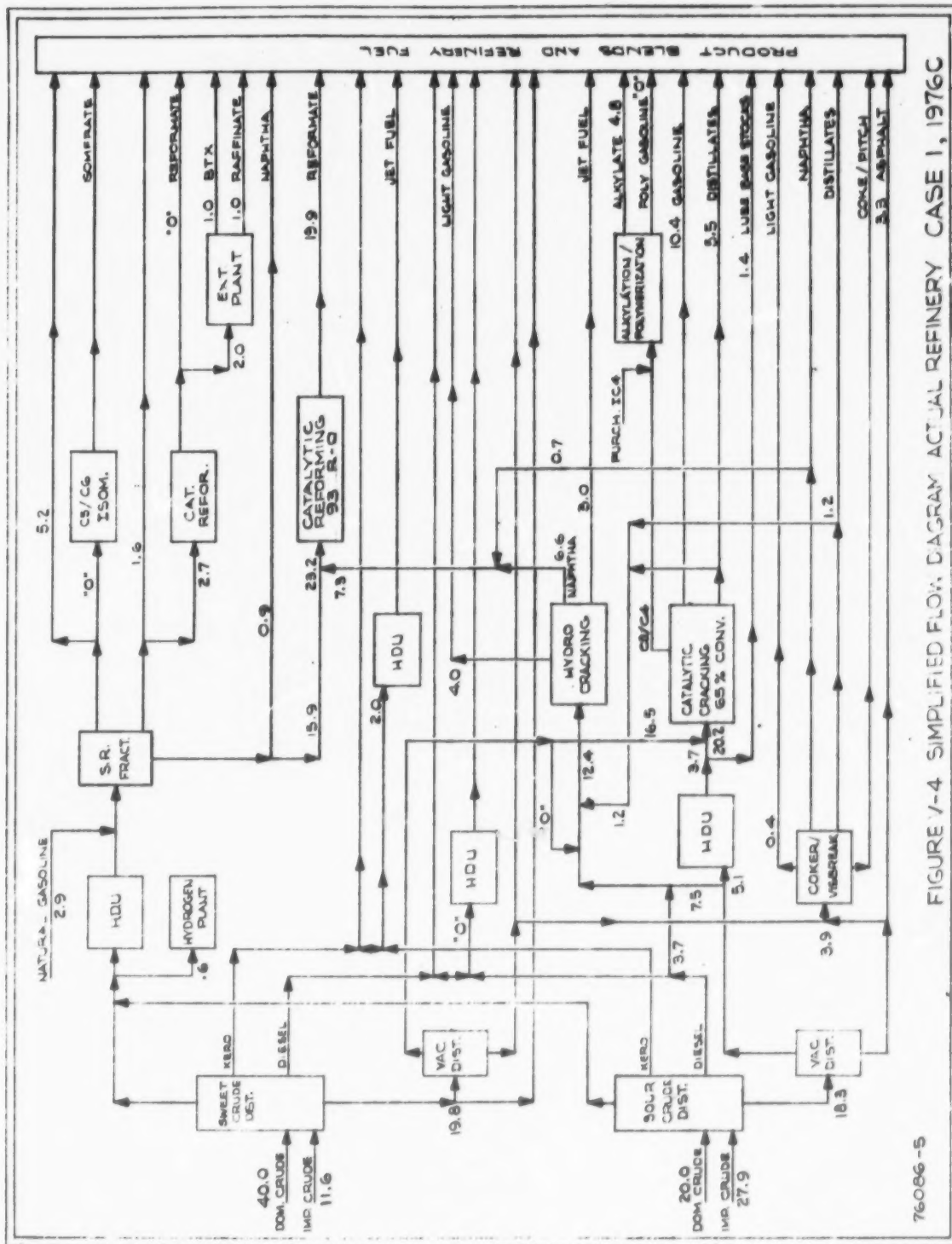


FIGURE 1-3 SIMPLIFIED FLOW DIAGRAM ACTUAL REFINERY CASE 1, 1976B



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FIGURE 7-4 SIMPLIFIED FLOW DIAGRAM ACTUAL REFINERY CASE 1, 1976C

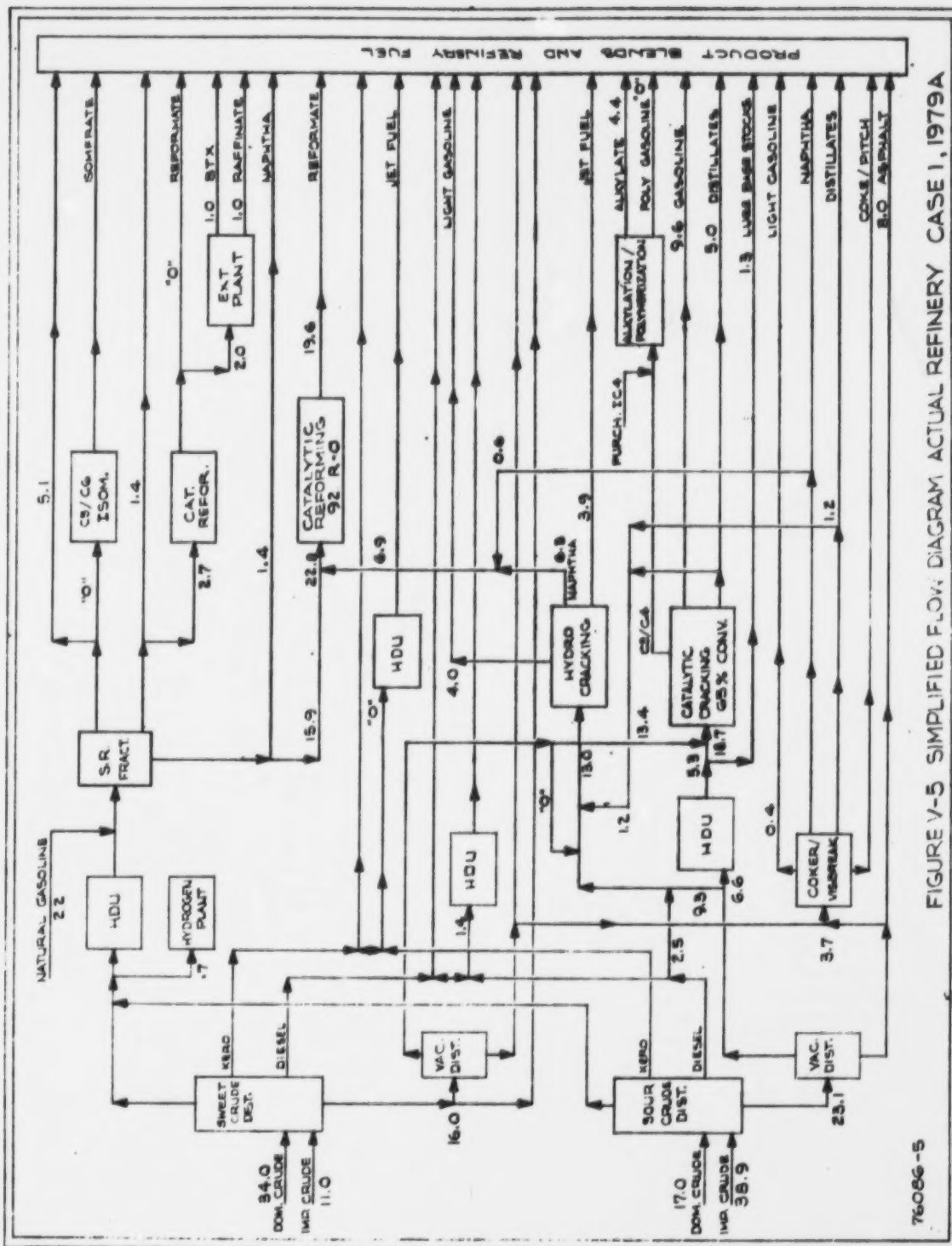


FIGURE V-5 SIMPLIFIED FLOW DIAGRAM ACTUAL REFINERY CASE 1, 1979A

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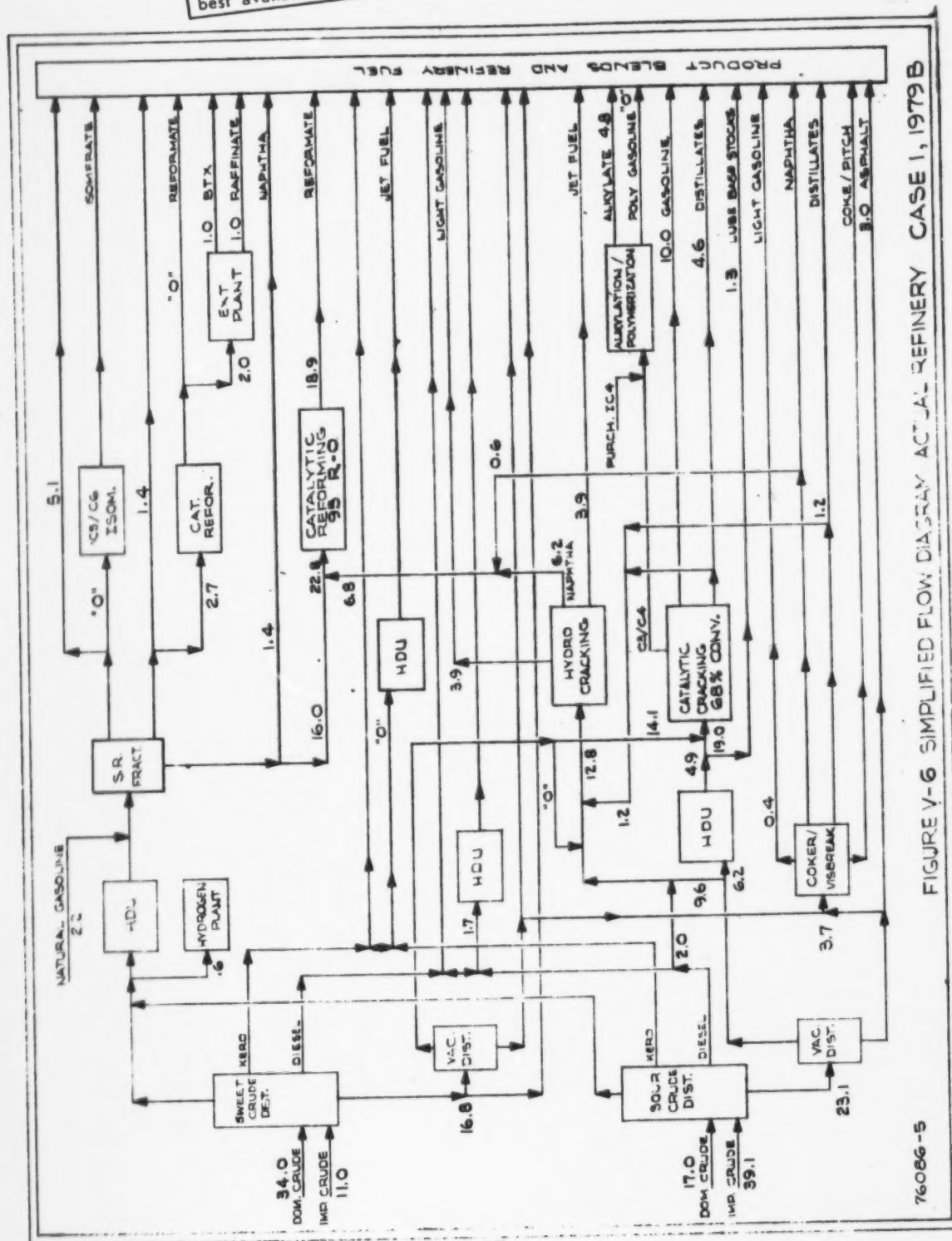


FIGURE V-6 SIMPLIFIED FLOW DIAGRAM ACTUAL REFINERY CASE 1, 1979B

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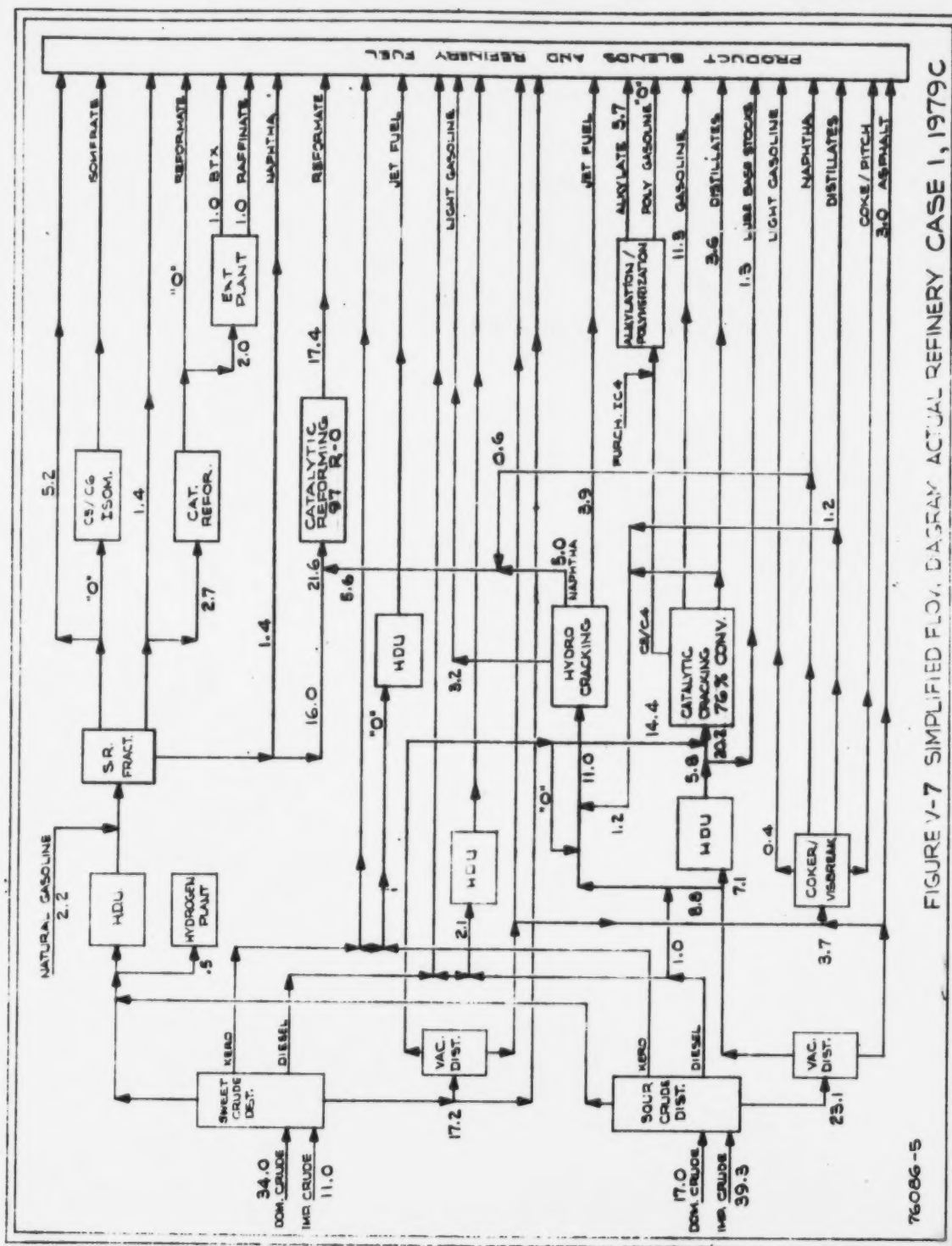
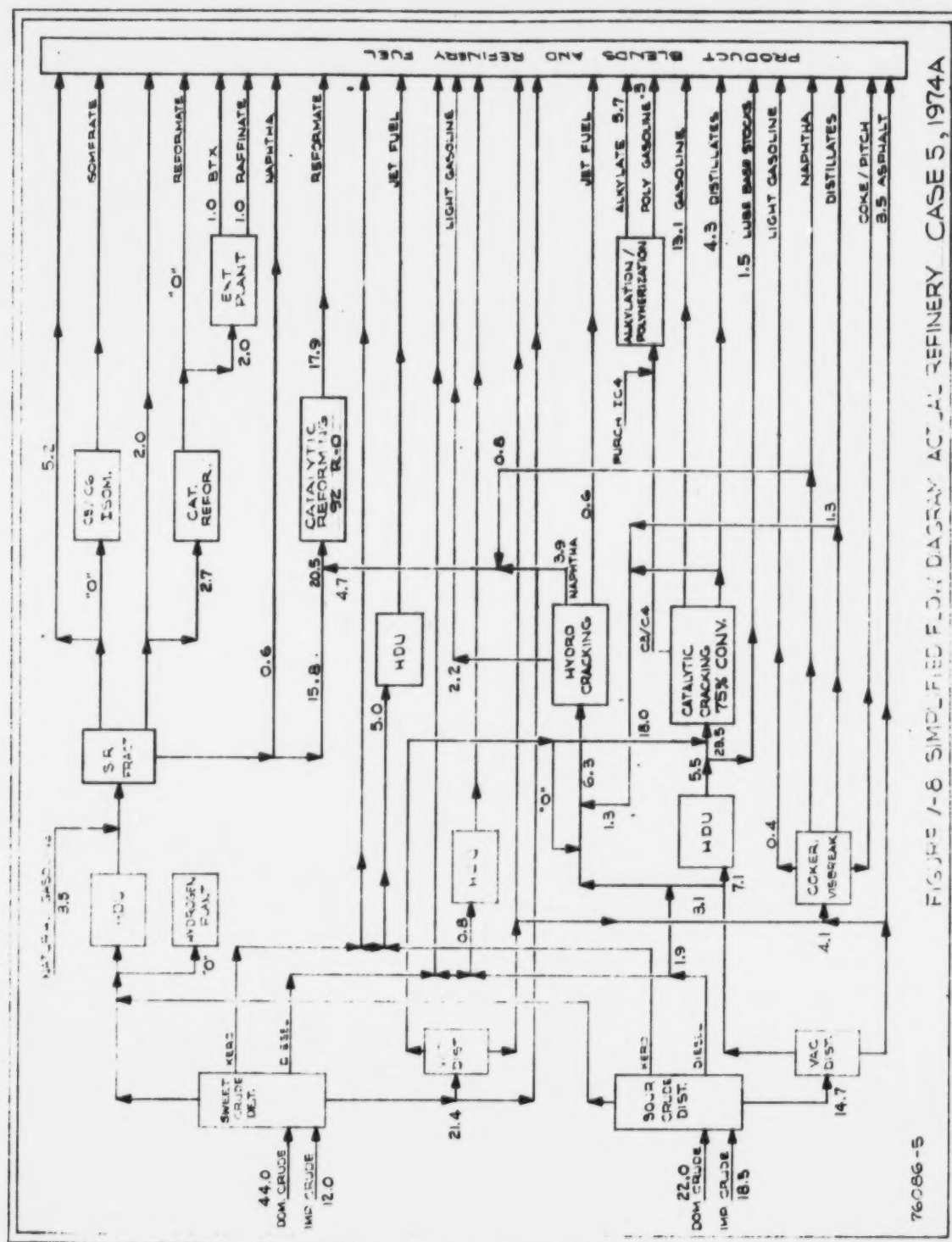
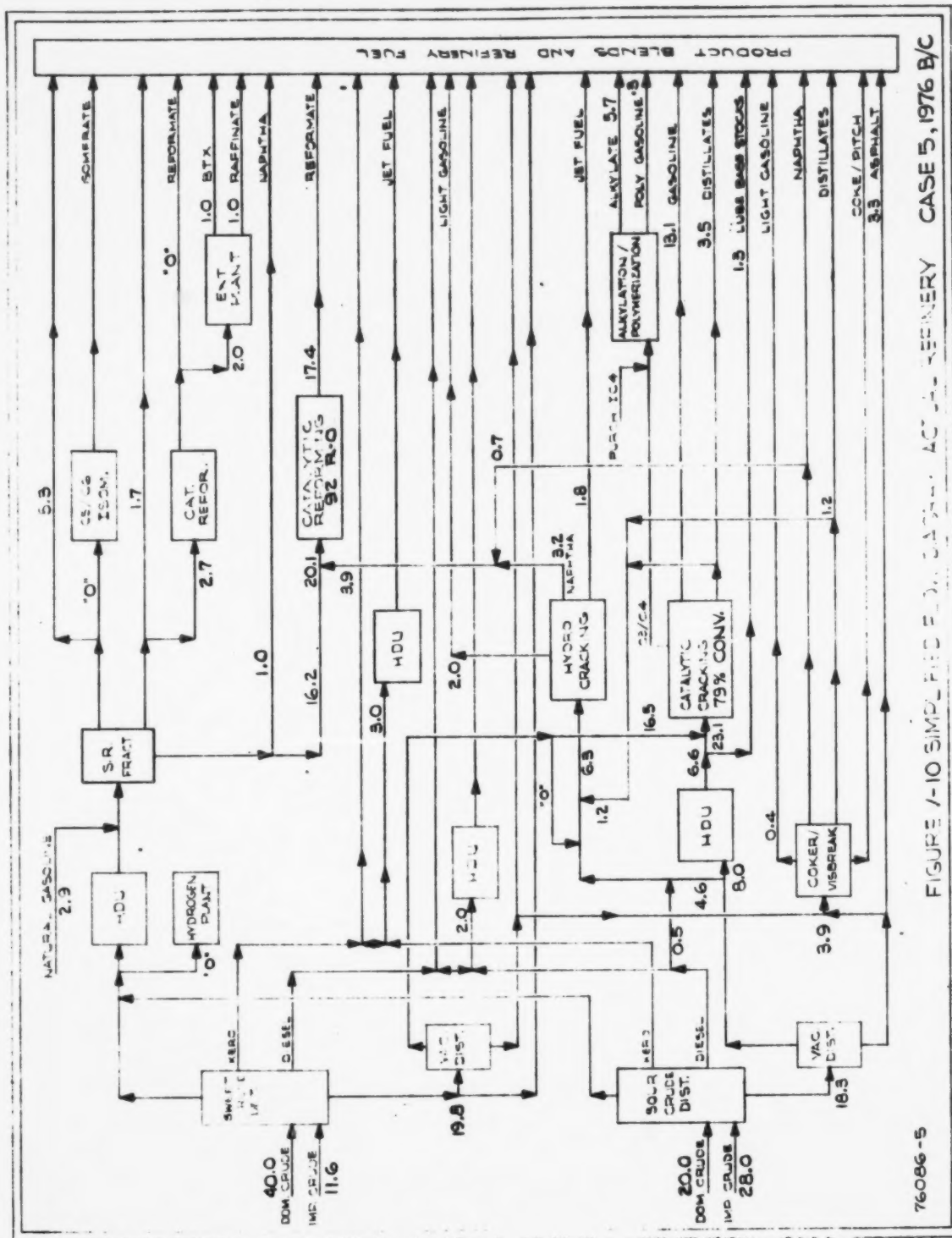


FIGURE V-7 SIMPLIFIED FLOW DIAGRAM ACTUAL REFINERY CASE 1, 1979C







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FIGURE 7-10 SIMPLIFIED FLOW DIAGRAM OF A REFINERY CASE 5, 1976 B/C

## VI. ANALYSIS OF REFINERY OPERATION

The purpose of the present section is to illustrate qualitatively the changes in refinery operation as lead-free gasoline is introduced and lead phase-down is implemented. This should allow additional insight and interpretation to the Model Results of Section III, but the results themselves will not be presented in the present section. In considering the changes in refinery operation due to the introduction of low lead gasoline, it is important to note that specific refinery operation modes are obtained through a cost optimization (specifically utilizing linear programming). Since the objective function is an optimized composite, the computer optimizes all cost elements simultaneously, including capital costs, raw material costs, and operating costs. Thus, we cannot interpret the refinery operation changes in terms of any one individual element (e.g., raw material intake, by-product production, capital costs, lead additive costs), for such individual elements represent only a portion of the overall optimization and may be outweighed by other elements in the selection of the refinery operating units. If it is deemed important that conserving raw material supply and maximizing by-products are the most important factors in refinery operation, then these scenarios can be achieved by appropriate use of high crude oil costs as data input to the model, as well as high revenues for by-products. In general, this was not attempted in the present study (except in Case 6, for gasoline and fuel oil maximization); rather, all input and output factors were set at projected realistic levels for the U.S. refining industry. There will therefore be limitations on the ability to isolate any single factor as the cause for the selection of specific refinery operating units, capacities and blending strategies in the present section.

### A. Crude Penalties

In order to evaluate the reasons for specific crude penalties, one must consider the overall refinery material balances, because significant changes in gasoline blending strategy are present when moving from Scenario A to B to C. Such evaluations of material balances allow a determination of, for example, the gasoline grade into which FCC gasoline is blended in Scenario A versus Scenario C. Furthermore, such material balance considerations also require evaluation of intakes of major processing units among the various scenarios.

Figures V-1 through V-10 present refinery flow diagrams for selected cases and scenarios. These diagrams supplement the following gasoline blending tables in that they define, among other things, the reformer severity, intake rate and naphtha source. For clarity, the diagrams are based on a nominal 100,000 B/CD refinery and the stream flow rates are completely enumerated in these figures only for gasoline streams. Since other product streams than gasoline, fuel oil and LPG are held fixed and can be determined from Tables V-1 through V-11, these were not included in Figures V-1 through V-10. The complete



refinery stock balances will be included, however, in the Phase II report.

Figure VI-1 provides a chronological summary of the optimum processing unit intakes for the Case 1, actual refinery, from 1974 through 1980, for Scenarios A, B, and C. On the catalytic reformer intake graphs, the numbers shown represent the clear octane operating severities for 1974, 1976, and 1980 for each scenario. The numbers on the catalytic cracking graphs represent conversion for the same runs.

One can observe a decline in the growth rate of the major conversion processing units (catalytic cracking and hydrocracking) in Scenario A over time. This is due to the increase in low sulfur residual fuel oil yield (primarily at the expense of gasoline). In order to compensate for the decreased growth rate of these conversion unit processes which produce higher octane gasoline blending components, the relative growth rate of catalytic reforming intake and severity are increased over time for Scenario A.

A consistent trend in unit intakes in Figure VI-1 can be noted in changing from Scenario A to B to C. The Scenario B unit intakes always fall between those of Scenarios A and C, although the difference is not always sufficient to justify a separate line in Figure VI-1. This figure suggests that the lead-free gasoline pool was produced by increasing FCC intake and severity to make more FCC gasoline (with high clear octane number) and more FCC olefins. The additional FCC olefins then lead to increased alkylation capacity, thus providing an additional gasoline blend component with a high unleaded octane number. Since additional gasoline is being introduced into the pool from these sources, hydrocracker intakes are decreased for Scenario C relative to Scenario A. This leads to less light hydrocracker gasoline (which requires lead for blending) and less heavy hydrocracker naphtha for reformer feed. From Figures V-5 through V-7, the changes in unit intakes are displayed for 1979 (note particularly that slight changes in the straight run component of the reformer intake take place simultaneously). In addition, it should be noted that, although catalytic reforming intake is decreased in Scenario C, the operating severity is increased. The purpose of this is to replace the octane barrels lost due to lead phase-down. However, the simultaneous changes of all of these unit intakes leads to a far lower crude penalty in producing a fixed gasoline production than would be expected due to reformer severity alone (the reformer yield losses may be calculated from Figures V-5 through V-7, and they are much larger than the crude penalties summarized in Table V-12, 1979).

It should also be noted that the clear pool octane number has increased from Scenarios A to B to C. The table below summarizes the clear pool octane numbers for Case 1, 1974A, 1976, and 1979. Because of the increased fraction of lead-free gasoline in the pool from 1976

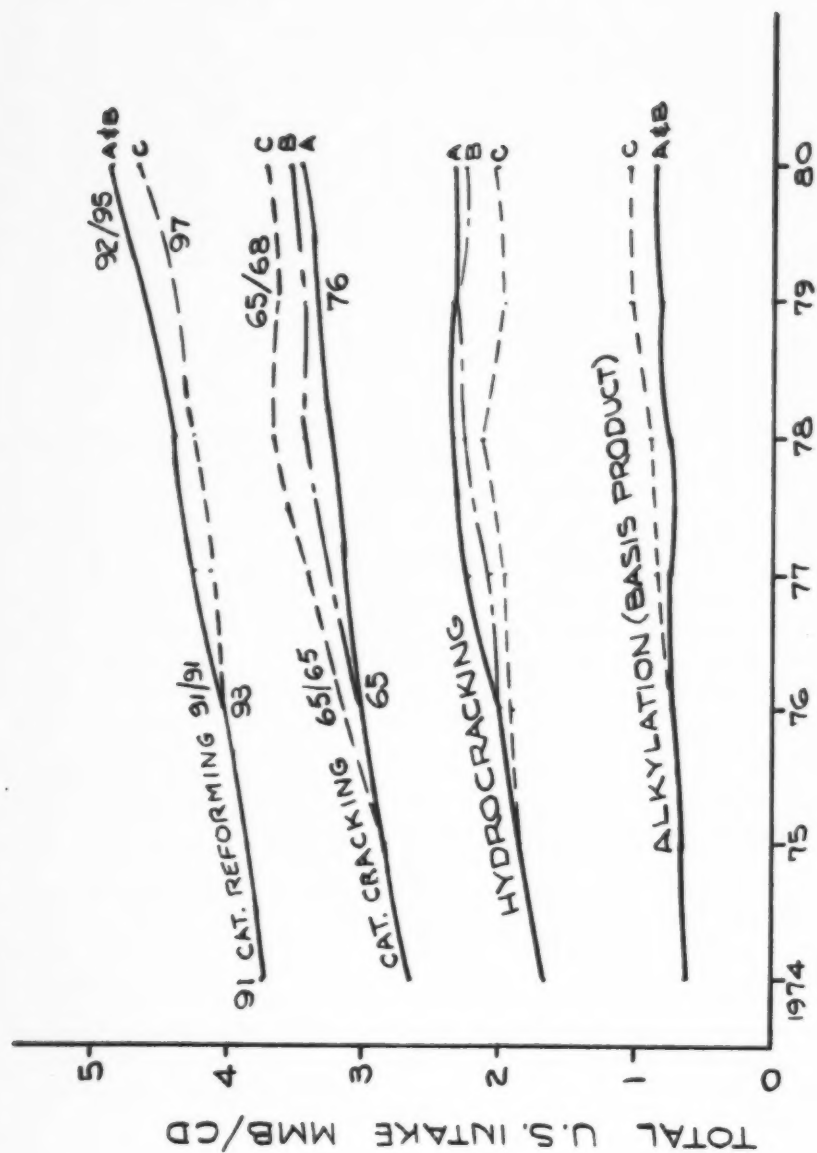


**FIGURE VI - 1**  
**PROCESSING UNIT INTAKES ACTUAL REFINERY**  
**CASE 1**

Gasoline Blending and Clear Pool Octane Numbers

|      | R-O  |      |      | M-O  |      |      |
|------|------|------|------|------|------|------|
|      | A    | B    | C    | A    | B    | C    |
| 1974 | 89.4 | -    | -    | 81.2 | -    | -    |
| 1976 | 89.6 | 89.6 | 90.0 | 81.2 | 81.2 | 81.4 |
| 1979 | 89.5 | 90.7 | 91.8 | 81.0 | 81.8 | 82.6 |

through 1979, the clear pool octane increases with time from 1976 to 1979. Hence, the increase in pool octane between Scenarios C and A becomes larger from 1976 to 1979.

It is important to note, however, that the average leaded research octane in Scenario A, 1979, is significantly higher than that of Scenario C, 1979. This is because of the higher pool lead level in Scenario A (see Table V-1), which thus provides a pool research octane of about 96 (fully leaded) compared to a pool octane for Scenario C of perhaps 93 (some leaded gasoline combined with unleaded gasoline). This lower octane level for Scenario C is, of course, a natural result of the case definitions of Section II, and is entirely consistent with lead phase-down regulations and announced octane requirements of new automobiles. However, the crude penalty for lead phase-down in Case 1 would thus be expected to be far lower than for a case for which the pool octane is held fixed after lead phase-down, for example. Such cases have been quoted as indicating a penalty for lead phase-down by some other sources, but we feel that such penalties are unrealistic because they are based on unrealistic assumptions.

Further information regarding the refinery operations used to achieve the lead-free gasoline pools of Scenarios B and C can be obtained by evaluating the gasoline blending strategies used for selected years. In Table VI-1 is shown the base case blend summary for Case 1, 1974, Scenario A. The refinery flow diagram for this case, shown in Figure V-1, illustrates the source of the intake streams for reforming, hydrocracking, and catalytic cracking. The scenarios for 1976 are shown in Tables VI-2 through VI-4 and the corresponding refinery flow diagrams are shown in Figures V-2 through V-4.

In 1974 and 1976, Scenarios A and B both require approximately the same severity of reformer and cat cracker operation with only 1976C requiring a high severity reforming (100 Clear RON). In 1976 there is still no need for high severity catalytic cracking operation even for Scenario C. However, comparison of Figures V-1 through V-4 shows that hydrocracker feed is being reduced in 1976 versus 1974 (actually, less new capacity is added), and is diverted to catalytic cracking for reasons discussed above. This also leads to decreased

Table VI - 1

Gasoline Blending Summary Case I, 1974 A

Units are MB/CD in 100 MB/D Refinery

| Component        | Gasoline Grade |         |           | Total |
|------------------|----------------|---------|-----------|-------|
|                  | Premium        | Regular | Lead-Free |       |
| 90 Reformate     | 4.27           | 12.39   | .65       | 17.31 |
| 95 Reformate     | 3.76           | -       | -         | 3.76  |
| Low Sev Cat Crk  | 5.68           | 4.14    | -         | 9.82  |
| Alkylate         | 4.56           | -       | -         | 4.56  |
| n Butane         | 1.73           | .83     | .10       | 2.66  |
| Light Hydrocrack | -              | 4.31    | -         | 4.31  |
| Coker Gasoline   | -              | .43     | -         | .43   |
| Natural Gasoline | -              | 2.63    | -         | 2.63  |
| Straight Run     | -              | 4.17    | .25       | 4.32  |
| Totals           | 20.0           | 28.90   | 1.00      | 49.90 |

reformer intake. Tables VI-2 through VI-4 show that the lead-free pool is produced by primarily using the reformate and alkylate previously in the leaded gasoline in Table VI-2. In addition, there is more high unleaded octane FCC gasoline and alkylate available in 1976C than 1976A, because of the unit intake adjustments discussed above. Also, as shown in Table V-1, the pool lead was decreased, although the premium and regular grade lead levels were increased. The presence of light hydrocracker gasoline in the lead-free pool for 1976 was unusual among the many cases run, because of its low unleaded octane number.

The more extreme case represented by a higher level of unleaded gasoline in the pool is summarized in Tables VI-5 through VI-7 and Figures V-5 through V-7. The changes in unit intakes in Figures V-5 through V-7 are again consistent with the trends from Scenario A to B to C noted above, but are more extreme for 1979. The FCC and reforming severities are significantly increased from Scenarios A to B to C, producing more high unleaded octane gasoline and more olefins. Because of reformer yield losses and decreased intake, the total quantity of reformate is decreased, but this is more than compensated for by increased FCC gasoline and alkylate. The lead-free gasoline pool may thus be achieved, as noted in Tables VI-5 through VI-7, by blending all the available reformate, and large fractions of FCC gasoline and alkylate in Scenario C relative to Scenario A. Hence, the lead-free pool requirements can be met without sacrifice of total gasoline (all scenarios produce 47,000 B/CD), or, otherwise stated, with little crude penalty. The crude penalties discussed in Section III C, by the way, would represent about 0.1% of the total gasoline

Table VI - 2

Gasoline Blending Summary Case 1, 1976 A

Units are MB/CD in 100 MB/D Refinery

| <u>Component</u> | <u>Gasoline Grade</u> |                |                  | <u>Total</u> |
|------------------|-----------------------|----------------|------------------|--------------|
|                  | <u>Premium</u>        | <u>Regular</u> | <u>Lead-Free</u> |              |
| 90 Reformate     | 2.73                  | 12.34          | -                | 15.08        |
| 95 Reformate     | 4.60                  | -              | .65              | 5.25         |
| Low Sev Cat Crk  | 5.50                  | 4.53           | -                | 10.03        |
| Alkylate         | 4.63                  | -              | .01              | 4.64         |
| n Butane         | 1.65                  | .90            | .10              | 2.65         |
| Light Hydrocrack | -                     | 4.13           | -                | 4.13         |
| Coker Gasoline   | -                     | .40            | -                | .40          |
| Natural Gasoline | -                     | 2.18           | -                | 2.18         |
| Straight Run     | -                     | 4.40           | .25              | 4.65         |
| Totals           | 19.11                 | 28.89          | 1.01             | 49.01        |

Table VI - 3

Gasoline Blending Summary Case 1, 1976 B

Units are MB/CD in 100 MB/D Refinery

| <u>Component</u> | <u>Gasoline Grade</u> |                |                  | <u>Total</u> |
|------------------|-----------------------|----------------|------------------|--------------|
|                  | <u>Premium</u>        | <u>Regular</u> | <u>Lead-Free</u> |              |
| 90 Reformate     | 1.28                  | 6.08           | 7.61             | 14.97        |
| 95 Reformate     | 3.32                  | -              | 2.03             | 5.35         |
| 100 Reformate    | -                     | -              | -                | -            |
| Low Sev Cat Crk  | 4.69                  | 5.35           | -                | 10.04        |
| Hi Sev Cat Crk   | -                     | -              | -                | -            |
| Alkylate         | 1.83                  | -              | 2.81             | 4.64         |
| n Butane         | .83                   | .56            | 1.25             | 2.64         |
| Light Hydrocrack | 1.76                  | 1.68           | .68              | 4.12         |
| Coker Gasoline   | -                     | .40            | -                | .40          |
| Natural Gasoline | -                     | 2.18           | -                | 2.18         |
| Straight Run     | -                     | 4.34           | .31              | 4.65         |
| Totals           | 13.71                 | 20.59          | 14.69            | 48.99        |



Table VI - 4

Gasoline Blending Summary Case 1, 1976 C

Units are MB/CD in 100 MB/D Refinery

| Gasoline Grade   |                |                |                  |              |
|------------------|----------------|----------------|------------------|--------------|
| <u>Component</u> | <u>Premium</u> | <u>Regular</u> | <u>Lead-Free</u> | <u>Total</u> |
| 90 Reformate     | -              | 5.89           | 5.74             | 11.63        |
| 95 Reformate     | 4.97           | -              | 2.03             | 7.00         |
| 100 Reformate    | -              | -              | 1.28             | 1.28         |
| Low Sev Cat Crk  | 4.17           | 6.23           | -                | 10.40        |
| Alkylate         | 2.67           | -              | 2.12             | 4.79         |
| n Butane         | .96            | .65            | 1.04             | 2.65         |
| Light Hydrocrack | .92            | .92            | 2.14             | 3.98         |
| Coker Gasoline   | -              | .40            | -                | .40          |
| Natural Gasoline | -              | 2.18           | -                | 2.18         |
| Straight Run     | -              | 4.33           | .35              | 4.68         |
| Totals           | 13.69          | 20.60          | 14.70            | 48.99        |

Table VI - 5

Gasoline Blending Summary Case 1, 1979 A

Units are MB/CD in 100 MB/D Refinery

| Gasoline Grade   |                |                |                  |              |
|------------------|----------------|----------------|------------------|--------------|
| <u>Component</u> | <u>Premium</u> | <u>Regular</u> | <u>Lead-Free</u> | <u>Total</u> |
| 90 Reformate     | 2.87           | 10.54          | -                | 13.40        |
| 95 Reformate     | 5.61           | -              | .59              | 6.20         |
| Low Sev Cat Crk  | 5.23           | 4.37           | -                | 9.60         |
| Alkylate         | 4.41           | -              | .01              | 4.42         |
| n Butane         | 1.68           | .77            | .09              | 2.54         |
| Light Hydrocrack | -              | 3.98           | -                | 3.98         |
| Coker Gasoline   | -              | .38            | -                | .38          |
| Natural Gasoline | -              | 1.66           | -                | 1.66         |
| Straight Run     | -              | 4.60           | .22              | 4.82         |
| Totals           | 19.80          | 26.29          | .91              | 47.00        |

Table VI - 6

Gasoline Blending Summary Case 1, 1979 B

Units are MB/CD in 100 MB/D Refinery

| <u>Component</u> | <u>Gasoline Grade</u> |                |                  | <u>Total</u> |
|------------------|-----------------------|----------------|------------------|--------------|
|                  | <u>Premium</u>        | <u>Regular</u> | <u>Lead-Free</u> |              |
| 90 Reformate     | -                     | -              | 8.38             | 8.38         |
| 95 Reformate     | -                     | -              | 4.73             | 4.73         |
| 100 Reformate    | -                     | -              | 5.80             | 5.80         |
| Low Sev Cat Crk  | 3.83                  | 4.23           | -                | 8.06         |
| Hi Sev Cat Crk   | -                     | -              | 1.97             | 1.97         |
| Alkylate         | 1.25                  | -              | 3.53             | 4.78         |
| n Butane         | -                     | .13            | 2.06             | 2.19         |
| Isobutane        | .28                   | -              | -                | .28          |
| Light Hydrocrack | 1.74                  | .71            | 1.74             | 3.92         |
| Coker Gasoline   | -                     | .38            | -                | .38          |
| Natural Gasoline | -                     | 1.66           | -                | 1.66         |
| Straight Run     | -                     | 3.18           | 1.66             | 4.48         |
| Totals           | 7.10                  | 10.29          | 29.60            | 46.99        |

Table VI - 7

Gasoline Blending Summary Case 1, 1979 C

Units are MB/CD in 100 MB/D Refinery

| <u>Component</u> | <u>Gasoline Grade</u> |                |                  | <u>Total</u> |
|------------------|-----------------------|----------------|------------------|--------------|
|                  | <u>Premium</u>        | <u>Regular</u> | <u>Lead-Free</u> |              |
| 90 Reformate     | -                     | -              | 5.66             | 5.66         |
| 95 Reformate     | -                     | -              | .19              | .19          |
| 100 Reformate    | -                     | -              | 11.52            | 11.52        |
| Low Sev Cat Crk  | -                     | 4.88           | -                | 4.88         |
| Hi Sev Cat Crk   | 3.61                  | -              | 2.73             | 6.34         |
| Alkylate         | 3.07                  | .83            | 2.79             | 5.69         |
| n Butane         | .02                   | .24            | 1.91             | 2.17         |
| Isobutane        | .37                   | -              | -                | .37          |
| Light Hydrocrack | 1.03                  | 2.20           | -                | 3.23         |
| Coker Gasoline   | -                     | .34            | .05              | .39          |
| Natural Gasoline | -                     | -              | 1.66             | 1.66         |
| Straight Run     | -                     | -              | 3.11             | 4.92         |
| Totals           | 7.10                  | 10.30          | 29.62            | 47.02        |

in Table VI-7. The trends in pool lead discussed above for 1976 are also evident in 1979.

Refinery flow diagrams for selected years of restricted unit capacities (Case 5) are shown in Figures V-8 through V-10, which can be compared to the unrestricted capacity runs (Case 1) in Figures V-1 through V-4. As can be seen by comparing Table V-1 to Table V-5, the product outturns from these cases are identical, but significant additional butanes must be purchased for Case 5 because of lower hydrocracking unit intakes. Comparison of the appropriate refinery flow diagrams shows how significantly different refining unit size distributions can provide the same product outturns from the same crude run. Hence, it is not surprising that the crude penalties and energy penalties were relatively insensitive to the case under evaluation, as discussed in Section III C.

The gasoline blending summaries for the flexibility study (ability to maximize either gasoline or fuel oil with lead phase-down) are shown in Tables VI-8 and VI-9, for winter operation and summer operation, respectively. From these tables, it is apparent that the reformer intake varied quite widely from summer to winter. The alkylate availability was much higher in the summer, due to the production of FCC olefins from higher FCC unit intakes (Table V-6).

The clear pool octane is higher in the winter, 91.0/82.6, than in the summer, 90.0/81.0. This is obtained by operating at a very much higher reformer severity in the winter than summer but, at the same time, not requiring any high severity cat cracking in the winter (Table V-17). This results from the fact that maximum fuel oil production is not consistent with maximum conversion of cat cracker feed to gasoline, and the pool octane must then be made up, producing high octane reformat blending stocks. Additional detailed discussion on Case 6 is contained in Section VI C.

Table VI - 8

## Gasoline Blending Summary Case 6, 1976 A Winter

Units are MB/CD in 100 MB/D Refinery

| Gasoline Grades   |                |                |                  |              |
|-------------------|----------------|----------------|------------------|--------------|
| <u>Component</u>  | <u>Premium</u> | <u>Regular</u> | <u>Lead-Free</u> | <u>Total</u> |
| 90 Reformate      | -              | 3.89           | -                | 3.89         |
| 95 Reformate      | 2.14           | 1.24           | .37              | 3.75         |
| 100 Reformate     | 8.40           | -              | .11              | 8.51         |
| Low Sev Cat Crack | -              | 6.63           | -                | 6.63         |
| Alkylate          | 2.13           | .93            | -                | 3.06         |
| Poly Gasoline     | -              | -              | .03              | .03          |
| n Butane          | 1.69           | 1.33           | .11              | 3.13         |
| Isobutane         | -              | .24            | -                | .24          |
| Light Hydrocrack  | .69            | 1.19           | -                | 1.88         |
| Coker Gasoline    | -              | .40            | -                | .40          |
| Natural Gasoline  | -              | 2.18           | -                | 2.18         |
| Straight Run      | -              | 4.74           | .14              | 4.88         |
| Totals            | 15.05          | 22.77          | .76              | 38.58        |

Table VI - 9

## Gasoline Blending Summary Case 6, 1974 A Summer

Units are MB/CD in 100 MB/D Refinery

| Gasoline Grades  |                |                |                  |              |
|------------------|----------------|----------------|------------------|--------------|
| <u>Component</u> | <u>Premium</u> | <u>Regular</u> | <u>Lead-Free</u> | <u>Total</u> |
| 90 Reformate     | -              | 11.19          | -                | 11.19        |
| 95 Reformate     | 4.70           | -              | .27              | 4.97         |
| 100 Reformate    | -              | -              | -                | -            |
| Low Sev Cat Crk  | -              | 5.20           | -                | 5.20         |
| H1 Sev Cat Crk   | 6.88           | 2.57           | .07              | 9.52         |
| Alkylate         | 5.74           | -              | -                | 5.74         |
| Poly Gasoline    | -              | -              | .32              | .32          |
| n Butane         | 1.46           | 1.13           | .09              | 2.68         |
| Light Hydrocrack | .57            | 1.16           | -                | 1.73         |
| Coker Gasoline   | -              | 1.12           | -                | 1.12         |
| Natural Gasoline | -              | 1.78           | -                | 1.78         |
| Straight Run     | -              | 5.10           | .25              | 5.35         |
| Totals           | 19.35          | 29.25          | 1.00             | 49.60        |

## B. Economics

The new capital investment for the period 1974-1980 is estimated to be about 8 billion dollars (1974 dollars) for all cases studied, except for Case 3 (7% gasoline growth), which is estimated to be 11.75 billion dollars. The table below shows a detailed summary of new capital investment for Cases 1, 2 and 3, A, B, and C plus Case 5.

TABLE VI-10  
Cumulative New Capital Investment Above 1974  
Billions Dollars (1974 \$)

|                    | 1975 | 1976   | 1977   | 1978   | 1979   | 1980   |
|--------------------|------|--------|--------|--------|--------|--------|
| Case 1 Complex (A) | 1.25 | 2.66   | 3.80   | 5.11   | 6.67   | 8.29   |
| Δ (B - A)          | 0    | (0.06) | 0.19   | 0.11   | 0.20   | 0.38   |
| Δ (C - B)          | 0    | 0.10   | 0.25   | 0.46   | 0.43   | 0.30   |
| Case 1 Actual (A)  | 1.25 | 2.55   | 3.92   | 5.14   | 6.48   | 7.86   |
| Δ (B - A)          | 0    | 0      | (0.05) | 0.08   | 0.13   | 0.13   |
| Δ (C - B)          | 0    | 0      | 0.03   | 0.07   | (0.29) | (0.11) |
| Case 2 Actual (A)  | 1.20 | 2.49   | 3.83   | 5.14   | 6.48   | 7.86   |
| Δ (B - A)          | 0    | 0      | (0.05) | 0.10   | 0.08   | 0.03   |
| Δ (C - B)          | 0.01 | 0.02   | 0.17   | (0.07) | (0.38) | 0.33   |
| Case 3 Actual (A)  | 1.61 | 3.42   | 5.23   | 7.82   | 9.61   | 11.75  |
| Δ (B - A)          | 0    | 0      | 0      | (0.08) | 0.16   | 0.29   |
| Δ (C - B)          | 0    | 0      | 0.08   | (0.31) | (0.33) | (0.44) |
| Case 5 (A)         | 1.09 | 2.29   |        |        |        |        |

Note: Δ(B-A) and Δ(C-B) are the incremental capital investments for each year.

This table also points out the high sensitivity of capital investment with parameter variation. This same sensitivity is also illustrated by Figure VI-2, which plots cumulative net capital investment for C-B and B-A for Case 1 Actual and Complex. It is not likely that Case 1 Actual will show a cumulative capital investment credit for C - B as is shown in this figure. What the studies do show is that in any given year the magnitude of the deltas (B-A or C-B) is small (less than 5%) of the capital investment in that year, i.e., the difference in capital investment between the two lead phase-down scenarios is too small to be accurately determined without more time. However, the new capital investment figures themselves are reliable and accurate. This study does show that new capital investment requirements are not sensitive to any of the parameters studied except for rate of gasoline growth. They also show that the model simulation "complex" requires a higher cumulative delta plant investment than the model simulation "actual".



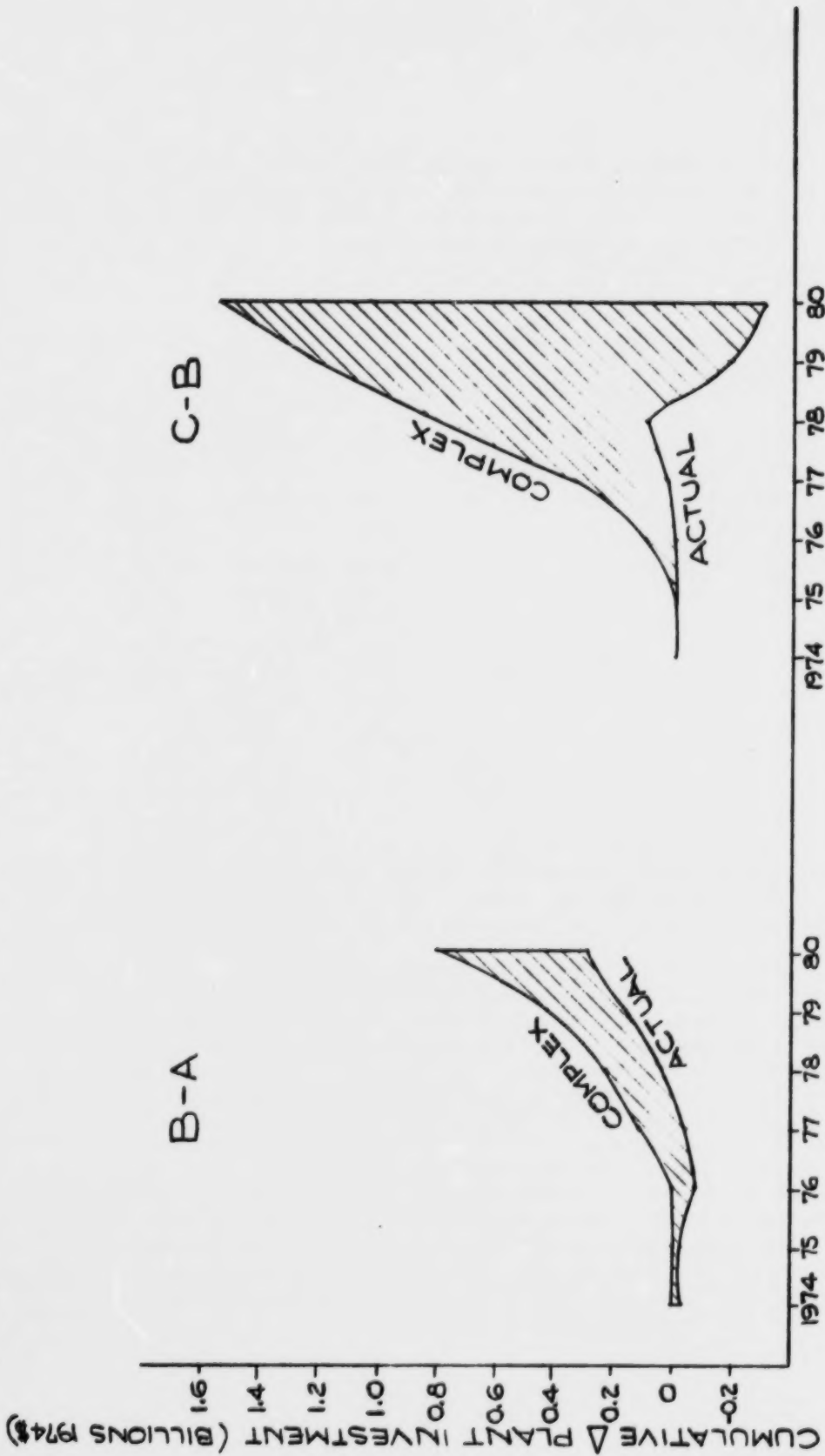


FIGURE VI-2  
DELTA CUMULATIVE INVESTMENT SUMMARY  
COMPLEX VS. ACTUAL

As an example of this consider the year 1979, Case 1 actual and complex. Tables V-23 and V-29 indicate that the "actual" refinery in 1979 Scenario B requires an additional investment of \$130,000,000 (1974 \$) relative to Scenario A and that Scenario C is \$290,000,000 cheaper in investment than Scenario B. For the complex refinery in the same year Scenario B is \$200,000,000 more expensive than Scenario A and Scenario C is \$430,000,000 more expensive than Scenario B. This same type of situation is also represented by the cumulative delta plant investments shown in Figure VI-2. In all cases for both "actual" and "complex" Scenario B is more expensive than Scenario A, with the increment being smaller for the actual refinery. However, the differences for B-C show an anomaly- Scenario C is cheaper than Scenario B for the years 1979 and 1980 for the actual refinery. For the complex refinery Scenario C is more expensive than B for all years.

This may be explained by reference to the Basic Data in Tables V-1 and V-8, a portion of which are condensed and tabulated below for Case 1.

TABLE VI-11  
Intakes MB/CD

|               | <u>ACTUAL</u> |      |      | <u>COMPLEX</u> |      |      |
|---------------|---------------|------|------|----------------|------|------|
|               | 79 A          | B    | C    | 79 A           | B    | C    |
| Cat Reform    | 4617          | 4609 | 4400 | 4369           | 4307 | 4418 |
| Cat Crack     | 3374          | 3432 | 3644 | 3814           | 4110 | 4181 |
| Hydro Crack   | 2349          | 2318 | 1984 | 1224           | 1107 | 1278 |
| Coking        | 599           | 599  | 599  | 599            | 599  | 599  |
| Alky          | 807           | 872  | 1038 | 929            | 1000 | 1013 |
| H2 Production | 2756          | 2568 | 2025 | 1387           | 1114 | 1213 |
| Desulf (NAP)  | 4606          | 4624 | 4660 | 4667           | 4700 | 4689 |
| (Gas Oil)     | 255           | 298  | 387  | 1253           | 1255 | 1221 |
| (VGO)         | 1193          | 1136 | 1289 | 1911           | 2056 | 1863 |

Note that in the "complex" relative to the "actual" refinery the catalytic cracker capacity and gas oil desulfurization capacities are substantially higher and the hydrocracking and hydrogen manufacturing capacities are substantially lower. The other process capacities are more nearly equal between the two scenarios. To explain the apparent anomaly between investment costs for Scenarios B and C, the table below is instructive.

TABLE VI-12

Delta Intakes MB/CD

|               | <u>79 ACTUAL</u> |                  | <u>79 COMPLEX</u> |                  |
|---------------|------------------|------------------|-------------------|------------------|
|               | <u>Delta B-A</u> | <u>Delta C-B</u> | <u>Delta B-A</u>  | <u>Delta C-B</u> |
| Cat Reform    | (8)              | (209)            | (62)              | 111              |
| Cat Crack     | 58               | 212              | 296               | 71               |
| Hydro Crack   | (31)             | (334)            | (117)             | 171              |
| Coking        | --               | --               | --                | --               |
| Alky          | 65               | 166              | 71                | 13               |
| H2 Production | (188)            | (543)            | (273)             | 99               |
| Desulf (NAP)  | 18               | 36               | 33                | (11)             |
| (Gas Oil)     | 43               | 89               | 2                 | (34)             |
| (VGO)         | (57)             | 153              | 145               | (193)            |

Scenario C (actual) will be less expensive in terms of investments than B because of the large reduction in cat reforming, hydrocracking and hydrogen plant capacities all of which are expensive units to build. Similar reductions did not occur in the complex refinery, and changes in capacities were positive and hence investment will increase from B to C. When looking at the numbers one must bear two important features in mind.

1) The LP program optimizes an objective function which represents a composite of capital, operation, and raw material costs (less by-product credits), not merely investment cost.

2) As discussed previously the "actual" refinery has a more restricted set of processing options relative to the complex refinery.

Hence, the two refinery sequences, actual and complex, will not have the same processes and capacities even though the product specifications, etc. are identical. The complex refinery has more freedom in stream blending.

To further illustrate this argument the penalty in

cents per barrel of total gasoline for the various cases is shown below:

| Complex |     | Actual |     |
|---------|-----|--------|-----|
| B-A     | C-B | B-A    | C-B |
| 2.0     | 3.9 | 1.4    | 4.0 |

Note that now the complex refinery has a smaller penalty for C-B than does the actual refinery, despite the fact that the investment was higher.

For 1979 Scenario C the Actual Refinery found it attractive to increase pool octanes (91.8/82.6 from 90.7/81.8) by a combination of increased catalytic cracking feed rate (3,644 from 3,432) and conversion (76 from 68). This allowed substantial reductions in the capital intensive processes (hydrocracking, catalytic reforming, and H<sub>2</sub> production). This operating mode was not as efficient from a raw material utilization and 133,000 B/CD of additional crude and volatiles were consumed. In the complex model only 41,000 B/CD additional raw material was needed for 1979 C.

Another aspect which must be considered is the impact of the various scenarios and cases on the construction industry. Figure VI-3 shows the total U.S. intake (1974 - 1980) for the catalytic cracking, catalytic reforming, hydrocracking and alkylation units for Case 1 complex. This particular case is selected for discussion in this section, because it represents the largest capital expenditure penalty (C-B), and therefore probably the most demanding new construction schedule. The maximum new construction in barrels per calendar day required for the period 1974 - 1980 (referred to Scenario A 1974) is shown below:

| Process                   | SCENARIO  |           |           |
|---------------------------|-----------|-----------|-----------|
|                           | A         | B         | C         |
| Alkylation                | 203,000   | 300,000   | 321,000   |
| Catalytic Reforming       | 1,078,000 | 1,043,000 | 1,087,000 |
| Catalytic Cracking        | 773,000   | 1,204,000 | 1,292,000 |
| Hydrocracking             | 237,000   | 254,000   | 249,000   |
| Hydrogen Prod.            | 889,000   | 545,000   | 610,000   |
| Desulfurization (Naphtha) | 1,631,000 | 1,660,000 | 1,660,000 |
| (Gas Oil)                 | 422,000   | 425,000   | 372,000   |
| (VGO)                     | 1,583,000 | 1,684,000 | 1,627,000 |

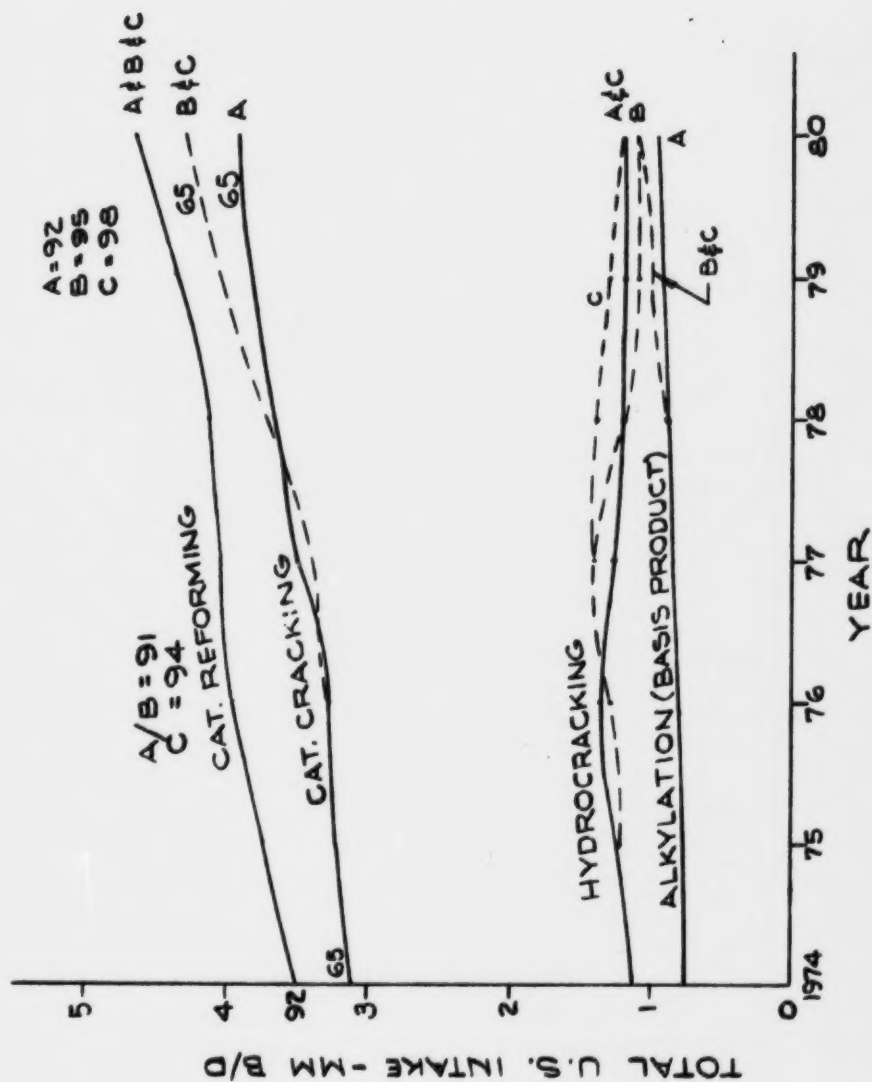


**FIGURE VI-3**  
PROCESSING UNIT INTAKES  
COMPLEX REFINERIES CASE 1



The new construction requirements for crude distillation, coking and vacuum distillation are not listed above because they are essentially the same for all cases studied other than Case 3 (7% gasoline growth). The differences in barrels per calendar day between B-A and C-B scenarios are tabulated below:

| <u>Process</u>      | <u>ΔB-A</u> | <u>%A</u> | <u>ΔC-B</u> | <u>%B</u> |
|---------------------|-------------|-----------|-------------|-----------|
| Alkylation          | 97,000      | 47.8      | 21,000      | 7.0       |
| Catalytic Reforming | (35,000)    | (3.25)    | 44,000      | 4.22      |
| Catalytic Cracking  | 431,000     | 55.8      | 88,000      | 7.31      |
| Hydrocracking       | 17,000      | 7.17      | (6,000)     | (2.36)    |
| Hydrogen Prod.      | (344,000)   | (38.7)    | 65,000      | 11.9      |
| Desulfurization:    |             |           |             |           |
| Naphtha             | 29,000      | 1.78      | -           | -         |
| Gas Oil             | 3,000       | 0.71      | (53,000)    | (12.5)    |
| VGO                 | 101,000     | 6.38      | (57,000)    | (3.38)    |

By comparison the maximum new construction in barrels per calendar day for Case 1 Actual is shown below. (This case had the smallest capital expenditure penalty for B-A and C-B).

| <u>Process</u>      | <u>SCENARIO</u> |           |           |
|---------------------|-----------------|-----------|-----------|
|                     | <u>A</u>        | <u>B</u>  | <u>C</u>  |
| Alkylation          | 185,000         | 315,000   | 404,000   |
| Catalytic Reforming | 1,129,000       | 1,079,000 | 968,000   |
| Catalytic Cracking  | 804,000         | 892,000   | 1,050,000 |
| Hydrocracking       | 654,000         | 623,000   | 366,000   |
| Hydrogen Prod.      | 1,246,000       | 964,000   | 681,000   |
| Desulfurization:    |                 |           |           |
| Naphtha             | 1,603,000       | 1,647,000 | 1,655,000 |
| Gas Oil             | None required   |           |           |
| VGO                 | 1,161,000       | 1,101,000 | 1,174,000 |

The differences in barrels per calendar day between B-A and C-B scenarios are tabulated below:

| <u>Process</u>      | <u><math>\Delta B-A</math></u> | <u>%A</u> | <u><math>\Delta C-B</math></u> | <u>%B</u> |
|---------------------|--------------------------------|-----------|--------------------------------|-----------|
| Alkylation          | 130,000                        | 70.3      | 89,000                         | 28.3      |
| Catalytic Reforming | (50,000)                       | (4.43)    | (111,000)                      | (10.3)    |
| Catalytic Cracking  | 88,000                         | 10.94     | 158,000                        | 17.7      |
| Hydrocracking       | (31,000)                       | 4.74      | (257,000)                      | (41.2)    |
| Hydrogen Prod.      | (282,000)                      | (22.6)    | (283,000)                      | (41.6)    |
| Desulfurization:    |                                |           |                                |           |
| Naphtha             | 44,000                         | 2.74      | 8,000                          | 0.48      |
| Gas Oil             | -                              |           | -                              |           |
| VGO                 | 60,000                         | 5.16      | 73,000                         | 6.22      |

A major conclusion to be drawn from these is that in general the incremental construction requirements between scenarios are quite small compared to the total construction requirements for any scenario between 1974 and 1980. For example, the total new refining capacity required between 1974 and 1980 is 6,027,000 B/D for Scenario A or an average of 5 new 200,000 B/D refineries per year.

### C. Refinery Flexibility

Section IV has stated that the refiner loses no flexibility in capability to maximize either gasoline or fuel oil due to lead phase-down through 1976, during which time he is constrained to the use of individual unit capacities as they exist today. Attached Table VI-13 summarizes refinery intakes and out-turns, selected unit intakes, and operating cost figures, which will now be discussed in more detail.

The total refinery crude run in Case 5 is shown to be 15,404 MB/CD for Scenarios A, B, and C, whereas for Case 6 the total crude run is 15,460 MB/CD for all scenarios, both summer and winter. As concluded in Section IV, there is no incremental crude penalty in comparing Scenarios A, B, and C in each category because the unleaded gasoline represents only 30% of the gasoline pool for B & C. It is not surprising that the total crude run for Case 6 exceeded that of Case 5, because the total product out-turns were designed to differ. Specifically, Case 6 Summer was intended to maximize gasoline relative to Case 5 and Case 6 winter was designed to maximize fuel oil. However, it is important to note that the Case 6 Winter and Summer results were obtained with the consumption of the same crude level, that is, the refinery was run to capacity in both cases as reflects current refinery practice in summer versus winter operation.

Purchased butanes also varied in a reasonable level in Table VI-13. Butanes are produced in the refinery principally by reforming, hydrocracking, and catalytic cracking. Other butane inputs are of course, purchased butanes and distillation of crude and natural gasoline. Butanes are consumed in the refinery by gasoline blending, LPG blending, and alkylation of olefins with isobutane. Natural gasoline was purchased to the limit of its availability, so it was invariant. Comparing Case 5 to Case 6, Summer, a minimum LPG production of 402 MB/CD was fixed in both cases to meet projected market demands, so it was invariant. Alkylation was run to capacity to produce gasoline alkylate, so it could not change between the cases. When 9.5 RVP gasoline was maximized in Case 6, only about 100 MB/CD additionally was produced compared to the 10 RVP gasoline production of Case 5. The increased butane production from increasing cracking unit intakes, coupled with the lower RVP gasoline in Case 6, allowed decreased purchase of butanes. Indeed, Case 5 C compared to Case 6 C, Summer, exhibited the following unit operations:

TABLE VI- 13

FLEXIBILITY ANALYSIS - MB/CD

1976

|                           | Case V, 10 RVP |        |        | Case VI, Summer, 9.5 RVP |        |        | Case 6, Winter 12 RVP |        |        |
|---------------------------|----------------|--------|--------|--------------------------|--------|--------|-----------------------|--------|--------|
|                           | A              | B      | C      | A                        | B      | C      | A                     | B      | C      |
| Domestic Sweet Crude      | 6,184          | 6,184  | 6,184  | 6,184                    | 6,184  | 6,184  | 6,184                 | 6,184  | 6,184  |
| Domestic Sour Crude       | 3,092          | 3,092  | 3,092  | 3,092                    | 3,092  | 3,092  | 3,092                 | 3,092  | 3,092  |
| Imported Sweet Crude      | 1,793          | 1,793  | 1,793  | 1,793                    | 1,793  | 1,793  | 1,793                 | 1,793  | 1,793  |
| Imported Sour Crude       | 4,327          | 4,335  | 4,335  | 4,391                    | 4,391  | 4,391  | 4,391                 | 4,391  | 4,391  |
| Sub Total Crude           | 15,396         | 15,404 | 15,404 | 15,460                   | 15,460 | 15,460 | 15,460                | 15,460 | 15,460 |
| Natural Gasoline          | 448            | 448    | 448    | 448                      | 448    | 448    | 448                   | 448    | 448    |
| Purchased Refinery Fuel   | 387            | 387    | 387    | 387                      | 387    | 387    | 387                   | 387    | 387    |
| Iso Butane                | 108            | 108    | 108    | 108                      | 108    | 93     | 108                   | 108    | 108    |
| Norm Butane               | 108            | 108    | 108    | 65                       | 86     | 3      | 108                   | 108    | 108    |
| Total Input               | 16,447         | 16,455 | 16,455 | 16,468                   | 16,489 | 16,391 | 16,511                | 16,511 | 16,511 |
| BTX                       | 155            | 155    | 155    | 155                      | 155    | 155    | 155                   | 155    | 155    |
| Naphtha                   | 247            | 247    | 247    | 247                      | 247    | 247    | 247                   | 247    | 247    |
| Kerojet                   | 897            | 897    | 897    | 897                      | 897    | 897    | 897                   | 897    | 897    |
| Kerosene                  | 216            | 216    | 216    | 216                      | 216    | 216    | 216                   | 216    | 216    |
| High Sulfur Fuel          | 155            | 155    | 155    | 155                      | 155    | 155    | 155                   | 155    | 155    |
| Lube Base Stocks          | 216            | 216    | 216    | 216                      | 216    | 216    | 216                   | 216    | 216    |
| Asphalt                   | 510            | 510    | 510    | 510                      | 510    | 510    | 510                   | 510    | 510    |
| Coke                      | 216            | 216    | 216    | 216                      | 216    | 216    | 216                   | 216    | 216    |
| Subtotal Fixed            | 2,612          | 2,612  | 2,612  | 2,612                    | 2,612  | 2,612  | 2,612                 | 2,612  | 2,612  |
| Prem Gaso                 | 2,953          | 2,118  | 2,118  | 2,992                    | 2,342  | 2,364  | 2,327                 | 1,820  | 1,820  |
| Reg Gaso                  | 4,468          | 3,185  | 3,185  | 4,526                    | 3,033  | 3,061  | 3,520                 | 2,356  | 2,356  |
| Lead-Free Gaso            | 155            | 2,273  | 2,273  | 153                      | 2,304  | 2,325  | 119                   | 1,789  | 1,789  |
| Subtotal Gaso             | 7,576          | 7,576  | 7,576  | 7,671                    | 7,679  | 7,750  | 5,966                 | 5,965  | 5,965  |
| Distillates               | 3,448          | 3,448  | 3,448  | 3,496                    | 3,434  | 3,312  | 4,696                 | 4,696  | 4,696  |
| Low Sulfur Fuel           | 1,639          | 1,639  | 1,639  | 1,593                    | 1,565  | 1,509  | 2,140                 | 2,140  | 2,140  |
| LPG                       | 402            | 402    | 402    | 402                      | 402    | 402    | 433                   | 433    | 433    |
| Total Products            | 15,677         | 15,677 | 15,677 | 15,774                   | 15,692 | 15,585 | 15,847                | 15,846 | 15,846 |
| Refinery Fuel             | 1,189          | 1,200  | 1,200  | 1,212                    | 1,212  | 1,234  | 1,028                 | 1,028  | 1,028  |
| Purch. Power-Mil KWH      | 63             | 63     | 63     | 63                       | 63     | 64     | 57                    | 57     | 57     |
| Lead Level-Prem.          | 1.27           | 1.81   | 1.81   | 1.29                     | 2.22   | 2.19   | .59                   | .82    | .82    |
| Reg.                      | 1.24           | 1.79   | 1.79   | 1.84                     | 2.74   | 1.85   | 1.27                  | 1.45   | 1.45   |
| Intake-Cat Reform         | 3,482          | 3,530  | 3,530  | 3,316                    | 3,381  | 3,527  | 3,480                 | 3,480  | 3,480  |
| Cat Crack                 | 3,664          | 3,565  | 3,565  | 4,040                    | 4,035  | 3,981  | 1,991                 | 1,993  | 1,993  |
| Hydrocrack                | 983            | 980    | 980    | 994                      | 1,007  | 1,002  | 986                   | 986    | 986    |
| Coking                    | 597            | 597    | 597    | 597                      | 597    | 597    | 597                   | 597    | 597    |
| Alky (Prod)               | 897            | 897    | 897    | 897                      | 897    | 897    | 478                   | 487    | 487    |
| H2 (MMSCFD)               | 772            | 741    | 741    | 931                      | 900    | 799    | 589                   | 580    | 580    |
| Desulf (Naph)             | 3,916          | 3,953  | 3,953  | 3,969                    | 3,969  | 3,969  | 3,941                 | 3,943  | 3,943  |
| (Gas Oil)                 | 669            | 770    | 770    | 289                      | 295    | 349    | 960                   | 960    | 960    |
| (VGO)                     | 1,339          | 1,240  | 1,240  | 1,721                    | 1,715  | 1,661  | 1,050                 | 1,050  | 1,050  |
| Operating Cost \$ MM      | 8.19           | 8.19   | 8.19   | 8.53                     | 8.65   | 8.50   | 7.05                  | 6.98   | 6.98   |
| Capital Charge \$ MM      | 12.80          | 12.75  | 12.75  | 12.94                    | 12.97  | 13.02  | 11.68                 | 11.69  | 11.69  |
| Cat Cracker Conversions   | 79             | 79     | 79     | 77                       | 77     | 82     | 65                    | 65     | 65     |
| Cat Reformer Severity     | 92             | 92     | 92     | 92                       | 92     | 92     | 97                    | 97     | 97     |
| Gasoline Pool Octanes R-0 | 90.6           | 90.5   | 90.5   | 90.0                     | 90.1   | 90.9   | 91.0                  | 91.0   | 91.0   |

|                                       | Case 5 C    | Case 6 C, Summer |
|---------------------------------------|-------------|------------------|
| FCC Intake                            | 3565 MB/CD  | 3981 MB/CD       |
| FCC Conversion                        | 79%         | 82%              |
| Hydrocracker Intakes                  | 980 MB/CD   | 1,002 MB/CD      |
| Cat Reformer Intake                   | 3,530 MB/CD | 3,527 MB/CD      |
| Cat Reformer Severity,<br>(Ron Clear) | 92          | 92               |

Since each of these units produce as much or more butanes for Case 6 C than Case 5, since the volume of the gasoline pool increased only 100 MB/CD for Case 6 C, Summer, and since the vapor pressure of the pool is lower for Case 6 C, decreased purchased butanes is expected. Also, the amount of purchased butanes should be less for Case 6 C, Summer than Case 6 A, Summer, by the same reasoning. Finally, because both isobutane and normal butane were purchased at \$6.74/bbl., the use of isobutane as a higher octane blend stock and as alkylation plant feedstock would require that purchases of normal butane be restricted preferentially, as observed in Scenarios A, B, and C of Case 6, Summer.

In Case 6, Winter, by contrast, minimum LPG production was raised to 433 MB/CD to meet projected market demands. In addition, the RVP of the gasoline was raised to 12 psi, the FCC intake was drastically reduced to maximize fuel oil production, and the butane production from the hydrocracker remained about constant. Furthermore, the propane production in the FCC unit (a primary blend component for LPG) was similarly reduced by two-thirds. Hence, it is not surprising that butane purchases had to be increased to the maximum possible level of 108 MB/CD in Case 6, Winter. Note, however, that the consumption of butanes for alkylation also decreased (due to limited FCC olefin supply), but not in sufficient amounts to offset the above effects. Finally, it can be seen from Table VI-13 that the reformer severity and intake was higher for the winter than the summer. Because of the decreased LPG production of the FCC unit under maximum fuel oil operation and the inability of the hydrocracker to make more LPG without increasing jet fuel and gasoline production, the incremental LPG had to be made on the reformers. This, of course, made LPG from gasoline (as desired under maximum fuel oil operation), but also significantly increased reformer severity (97 in winter versus 92 in summer) and thus increased gasoline pool octane. Referring to Table VI-13 it can be seen that Case 6 A had a summer pool octane of 90.0 whereas the winter octane for Case 6 A was thereby increased to 91.0, in order to meet LPG demands. By contrast, Case 6 C Summer pool octane was 90.9 in order to meet unleaded gasoline requirements; hence, the increase of Case 6 C Winter to a pool octane of 91.0 to meet LPG demands resulted in no dramatic penalty in refinery flexibility. It may thus be concluded that increased LPG market demands due to natural gas curtailments will allow unleaded gasoline to be produced in the winter with no flexibility penalty. In general, strong market prices for LPG



in the future are very important in that they will cause a significant shift in economic incentives to the refiner, thereby making past experiences an inaccurate predictor of future operating penalties regarding unleaded gasoline.

In this regard, it is important to note that, although the Case 6, Summer, results do not deviate from normal refinery practice (i.e. refinery gasoline production is not limited by purchased butanes), the Case 6, Winter, results are atypical. This is due to the rather extreme variations in FCC intake allowed in the absolute maximization of fuel oil in the winter. For example, although the Winter results represent refinery capability, gasoline demand in the December, 1973, substantially exceeded 6,000 MB/CD, so this does not represent refinery practice. Hence, even though refiners often directed propane or butane to fuel in the winter (before the strong LPG market demand), the extreme situation of Case 6, Winter, does not necessarily conflict with this practice. Finally, the low purchases of butanes in Case 6, Summer, may not actually take place if LPG market pressures increase. However, it is encouraging to note that, since the Summer butane purchases are less than projected availability, the refiner still has flexibility for additional LPG production if prices justify it. Indeed, Scenario C has the greatest flexibility for increased LPG production, due to the increased propane and butane production described above in making lead-free gasoline.

As shown in Table VI-13 total refinery input is generally less for Case 6, Summer, than for Case 6, Winter, due to the reasons described above for lower butane purchases. Also, as discussed above for total crude run, Case 5 and Case 6 total inputs cannot be expected to be identical, due to different product out-turns resulting from Case 6.

As shown in Table VI-13 all product out-turns other than gasoline and fuel oil were constrained to be identical by fixed market demands. The distribution among the several gasoline grades in Scenarios A, B, and C was set by expected market demand, and was invariant. The yield to crude varied from about 40% in the winter to a maximum of about 50% in the summer, which is reasonable in terms of refinery capability (but not refinery practice). It has been noted in Section III that the capability for maximizing gasoline is not decreased in Scenario C relative to Scenario A in the summer (Case 6). In fact, it is increased somewhat! In addition, the clear pool octane numbers for Case 6, Summer, shown below illustrate a significant improvement of pool octane accompanying this increased production:

| Scenario                    | A    | B    | C    |
|-----------------------------|------|------|------|
| Pool Research Octane, Clear | 90.0 | 90.1 | 90.9 |
| Pool Motor Octane, Clear    | 81.0 | 81.0 | 81.6 |

The increased clear gasoline production is seen from Table VI-13 to be achieved by increasing reformer feed rate significantly and increasing FCC conversion. Increased reformer feed is achieved in part by inclusion of more coker naphtha in the reformer feed; the major contribution, however, is obtained by removing straight run naphtha from the jet fuel pool and directing it to the gasoline pool after reforming. The contribution of FCC gasoline to the pool is only slightly increased for Scenario C relative to Scenario A because the increased FCC conversion is offset by decreased FCC feed rate. By this combination of changes in the refinery blend structure, it is apparent that the lead-free gasoline yield can be greatly increased and the pool octane can be increased without increasing reformer severity. The jet fuel directed to reformer feed was replaced by increasing the recycle cut point on the hydrocracker and by desulfurizing additional light gas oil. Note also, that the octane number of the premium grade gasoline was also achieved by a two-fold increase in lead level in that grade of gasoline. The increased production of FCC olefins in Scenario C versus Scenario A could not be used in Case 6 as alkylation plant feedstock because of capacity limitations on that plant; if the refinery were "debottlenecked" by increasing alkylation plant capacity (additional isobutane can also be purchased in Scenario C), even more lead-free gasoline could have been produced. With the limited plant capacity, however, the olefins were directed to refinery fuel in the present model; in actual refinery practice, these olefins would have higher value as a petrochemical feedstock.

Because of the increased production of refinery  $C_1 - C_2$  gases associated with more lead-free gasoline production and more  $C_4$  production (resulting in less  $C_4$  purchases), it is not surprising that the total product out-take is decreased in Case 6, Summer, as the refinery is changed to meet the product requirements of Scenarios A, B and C. Since more energy is similarly required to produce the higher pool octane and the higher  $C_1 - C_2$  yield from the fixed crude slate, it is not surprising to observe that the total energy requirements (purchased power, refinery fuel and FCC coke) are increased in Scenario C in the summer. Also, as shown in the table below, the arguments regarding the conditions required to meet the LPG demands in the winter would suggest that little or no incremental energy is required to meet the lead-free pool demands in the winter.

TOTAL ENERGY USED, MB/CD FOE

| Scenario       | A    | B    | C    |
|----------------|------|------|------|
| Case 6, Summer | 1428 | 1428 | 1450 |
| Case 6, Winter | 1175 | 1175 | 1175 |
| Case 5         | 1394 | 1402 | 1402 |

Although the product out-turns in Case 5 are designed to differ from those of Case 6 (thus preventing a detailed comparison of the cases), the energy consumption is generally consistent with the average of the Summer and Winter, Case 6, energy consumptions.

The capital and operating charges shown in Table VI-13 are similarly consistent between Cases 5 and 6. These charges are significantly less for Case 6, Winter, relative to Case 6, Summer, as would be expected due to the maximum fuel oil versus maximum gasoline operations. The primary cost advantages in the Winter, therefore, are due to the lower FCC unit,  $H_2$  unit, and V.G.O. desulfurization (for FCC feed, in part) intakes, which outweigh the increased gas oil desulfurization costs. For the Scenarios A, B, and C within the Summer and Winter cases, the economic penalties are so small as to be insignificant. Generally, however, the capital costs follow the energy requirements, as expected, and for the same reasons. The operating costs in the Summer are highest for Scenario B due to lead charges; the slight improvement for Scenario C relative to Scenario A is due to the effects of lower lead requirements outweighing the slight incremental contribution of capital charges to operating costs.

#### D. Energy Penalties

##### 1979 Actual vs. Complex

The total energy consumed (purchased power, refinery fuel, and cat cracking coke) for Case 1 actual and complex for the year 1979 is summarized below -- both energy and crude are reported in F.E.O. barrels (see Tables V-33 and V-40):

|             | Actual |       |       | Complex |      |       |
|-------------|--------|-------|-------|---------|------|-------|
|             | A      | B     | C     | A       | B    | C     |
| Total-MB/CD | 1636   | 1654  | 1676  | 1595    | 1617 | 1647  |
| % Crude     | 10.09  | 10.18 | 10.29 | 9.83    | 9.93 | 10.13 |

This shows that for any given scenario, A, B, or C, the complex refinery consumes less energy, both as a total quantity and as a percent of crude. This is to be expected since the processes used in the "actual" refinery (Table VI-11) emphasized hydrocracking and hydrogen production, both of which consume large amounts of energy (relative to the decreased hydrocracking of Case 1 Complex). However the installed U.S. average hydrocracking capacity in 1974 is slightly less than 900 MB/CD (Table V-5), whereas the 1974 hydrocracking capacity in 1974 for Case 1, Actual, is 1,695 MB/CD (Table V-1) and for Case 1, Complex, is 1,127 MB/CD (Table V-8). Hence, the absolute level of energy consumption tabulated above may be too large compared to the expected levels in 1979 for all the above scenarios.

The above table also shows that Scenario B consumes more energy than A and that Scenario C consumes more energy than B. This is true when the consumption is expressed either in total barrels of equivalent fuel oil or as a percent of crude. As expected the refinery internal generation of fuel increases from A to B to C. For example, in 1976 and 1979, the internal fuel generation (F.O.E., MB/CD) is shown below:

|      | A           | B           | C           |
|------|-------------|-------------|-------------|
| 1976 | 375 (31.6%) | 375 (31.6%) | 388 (32.6%) |
| 1979 | 419 (29.8%) | 465 (32.7%) | 506 (35.1%) |

The numbers in parenthesis indicate the percent of total refinery fuel consumed which is internally generated. Note that these percentages also increase from A to B to C as would be intuitively expected -- the processes to make lead-free gasoline such as reforming also produce significant quantities of fuel, as discussed extensively in Section VI C.

TABLE VI - 14  
Total Energy Consumed  
(Actual Refinery)

|        |      | MB/CD |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
|--------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
|        |      | 1974  |      |      | 1975 |      |      | 1976 |      |      | 1977 |      |      | 1978 |      |      | 1979 |      |      | 1980 |      |  |
|        |      | A     | B    | A    | B    | C    | A    | B    | C    | A    | B    | C    | A    | B    | C    | A    | B    | C    | A    | B    | C    |  |
| Case 1 | 1227 | 1227  | 1305 | 1305 | 1305 | 1305 | 1386 | 1386 | 1392 | 1470 | 1474 | 1486 | 1550 | 1557 | 1573 | 1636 | 1654 | 1676 | 1739 | 1773 | 1784 |  |
| Case 2 | 1227 | 1227  | 1306 | 1305 | 1308 | 1386 | 1392 | 1393 | 1470 | 1482 | 1499 | 1550 | 1567 | 1583 | 1636 | 1668 | 1696 | 1739 | 1787 | 1806 |      |  |
| Case 3 | 1227 | 1227  | 1334 | 1334 | 1334 | 1454 | 1454 | 1458 | 1578 | 1578 | 1597 | 1717 | 1721 | 1742 | 1851 | 1873 | 1909 | 2010 | 2053 | 2077 |      |  |
| Case 4 |      |       |      |      |      |      | 1386 | 1386 | 1392 |      |      |      |      |      |      | 1636 | 1642 | 1686 |      |      |      |  |
| Case 5 | 1238 | 1238  | 1308 | 1316 | 1316 | 1394 | 1402 | 1402 |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Case 7 |      |       |      |      |      |      |      |      |      |      |      |      |      |      |      | 1636 | 1653 | 1673 |      |      |      |  |



TABLE VI - 15

Total Energy Consumed  
(Complex Refinery)

MB/CD

|        | 1974 |      |      | 1975 |      |      | 1976 |      |      | 1977 |      |      | 1978 |      |      | 1979 |      |      | 1980 |      |      |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|        | A    | B    | C    | A    | B    | C    | A    | B    | C    | A    | B    | C    | A    | B    | C    | A    | B    | C    | A    | B    | C    |
| Case 1 | 1211 | 1212 | 1286 | 1286 | 1286 | 1286 | 1362 | 1360 | 1365 | 1435 | 1442 | 1458 | 1510 | 1518 | 1540 | 1595 | 1617 | 1647 | 1698 | 1735 | 1768 |
| Case 2 |      |      |      |      |      |      | 1363 | 1368 | 1376 |      |      |      |      |      |      | 1596 | 1656 | 1678 |      |      |      |
| Case 3 |      |      |      |      |      |      | 1435 | 1433 | 1438 |      |      |      |      |      |      | 1807 | 1845 | 1873 |      |      |      |
| Case 4 |      |      |      |      |      |      | 1363 | 1357 | 1366 |      |      |      |      |      |      | 1595 | 1601 | 1657 |      |      |      |

Tables VI-14 and VI-15 present the total energy consumed for the years 1974 to 1980 for various cases, for the "actual" refinery and the "complex" refinery, respectively. Both these tables show that for any given scenario (A, B, C) the energy consumption is essentially independent of the parameters varied except for Case 3 -- a 7% per year growth in gasoline demand illustrates that a larger gasoline pool will increase energy consumption as well as the penalty between scenarios. Changing the octane number from 92/84 to 93/85 RON/MON (Case 2), altering the lead-free demand structure (Case 4), restricting capacity (Case 5), or reducing the premium demand (Case 7) had very little effect on energy consumption. These two tables also show that, for reasons discussed above, Scenario B consumes more energy than A, and Scenario C more energy than B. However, in some years, particularly 1974 - 1976, the differences are very slight, being less than Case 5 versus Case 1 simulations of the refining industry. Specific conclusions regarding energy penalties are discussed in Section III C.

## VII. RECOMMENDATIONS FOR FUTURE STUDIES

The main emphasis of future studies on the impact of lead-free gasoline and lead phase-down should focus on classifying simpler modules of U.S. refining capacity to specifically address regional and atypical refining configurations and the sensitivity of capital investment requirements. At a minimum one should consider at least one composite refinery for each PAD (Petroleum Administration for Defense) district. The unique crude supply and product demand/specification patterns should be developed for use in the regional models.

Several individual refining modules should be postulated to represent different categories of actual refineries by selectively dropping one or several potential processing units from those available for optimization. For example, a refinery would be created with only catalytic cracking, alkylation and catalytic reforming as the sole secondary processing options. (If this configuration refinery needs to process sour crude, then additional hydrotreating facilities would also be made available.) Then a coker should be added and coke out-turn increased above the composite volume produced within the region to that level of production experienced by those refineries who actually have cokers (which will be two to three times the average production level within the district). These refineries would, of course, make much less residual fuel oil. A hydrocracker can be added in lieu of coking and also the hydrocracking/reforming configuration could be analyzed with no catalytic cracking/alkylation allowed. These models would selectively consider varying by-products by increasing respective levels of manufacture to that experienced by the major producers of the individual by-products. In this category we would include BTX and other petro-chemical feed stocks, as well as asphalts, lubes and other specialties.

Finally, we would recommend that further studies be made of seasonality in refinery crude supply, operations and product out-turn, although this overview analysis considered some seasonal variations.